Planning Assistance to States, Section 22 Program
Lake Sinissippi Improvement District, Dodge County, Wisconsin
Alternatives Report

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CONTENTS

TABLES

FIGURES

APPENDICES

Introduction and Management Summary

The Lake Sinissippi Improvement District (LSID) of Hustisford, Wisconsin, has partnered with the Corps of Engineers Rock Island District in an effort to obtain planning guidance to address the issues of sedimentation, shoreline erosion, lost wetlands, lost emergent plant habitats and lost islands on Lake Sinissippi. This report indentifies potential opportunities that the LSID can further pursue to address these issues.

One of the important conclusions of this investigation is the limited availability of suitable upland placement sites for dredged material around Lake Sinissippi. Securing suitable placement sites within proximity of priority dredging areas and maximizing in-lake use and beneficial use and removal of sediment will be key objectives for future work.

This report does not identify any one particular solution to the issues of concern, but rather identifies multiple opportunities to address these issues. Several of the opportunities identified can potentially address a combination of the issues at once such as beneficially using sediment to recreate islands and wetland habitats. It is intended that the LSID would take the information contained in this report to prioritize and identify potential projects that would fit their immediate needs, long term needs, and budget. Information such as sediment locations, sediment volumes, and potential placement sites with capacities, sediment removal methods and shoreline stabilization methods can be utilized to further develop detailed plans for the submittal of permit applications and requests for construction quotations and to seek grant funding.

Of the projects that the LSID chooses to construct, how the construction will be completed is very significant to the cost of the project. The Corps recommends that the LSID gather input or request proposals from several potential contractors to identify cost effective methods of construction before finalizing plans. Gathering input from potential contractors could guide the LSID to alter or change plans to fit certain construction methods in order to obtain the most value for dollars spent. There are several different methods mentioned in this report on how to remove sediment as well as placing it. Not all contractors are alike; they have different skills, experiences, and more importantly different types of construction/dredging equipment to move sediment. Consulting with these contractors would be very beneficial to the LSID in gaining ideas for planning and delivering projects smoothly through construction and completion and to complete the work at minimal cost.

I. BACKGROUND

The project is located on Lake Sinissippi, a 2,800-acre river impoundment in Dodge County, Wisconsin, (Figure 1). The lake has a drainage area of 511 square miles of primarily agricultural land (Table 1 and Figure 2). About 90% of the lake watershed area lies above the Horicon Dam, including the 32,000-acre Horicon Marsh and Rock River headwaters (Figure 3). The Dead Creek subwatershed and adjacent lake area with smaller tributaries comprise the remaining 10 percent of the watershed. Tributary waters include inflow from the Rock River (65 percent of water inflow) and Dead Creek (4 percent of water inflow) as shown in table 2. The lake was created in 1845, when a dam was constructed across the Rock River in Hustisford, Wisconsin.

Lake Sinissippi is a shallow, unstratified river impoundment with conditions of turbidity, planktonic algae, and reduced oxygen content. Water quality data collected by the LSID show that the lake is highly eutrophic with summer levels of chlorophyll *a* of 180.5 ug/l, total phosphorus of 0.26 mg/l, total Kjeldahl nitrogen of 3.03 mg/l, total suspended solids of 44 mg/l, total 5-day BOD of 16 mg/l, and Secchi disk depth of less than 1 foot. Graphical representation of dissolved oxygen concentrations and depth typically shows a clinograde curve.

Much of the once abundant wetlands in the watershed has been converted to cropland. The loss of wetlands, combined with exposed soils and intensive farming, contributes to runoff of sediment and nutrients. Agricultural fertilizer, animal waste, eroded soil, municipal stormwater runoff, and marsh sediment are major sources of pollutants entering the lake.

Soils in the lake area comprise a combination of wetland (hydric) soils in the lowland areas and glacial soils on the glacial moraines that form the upland features.

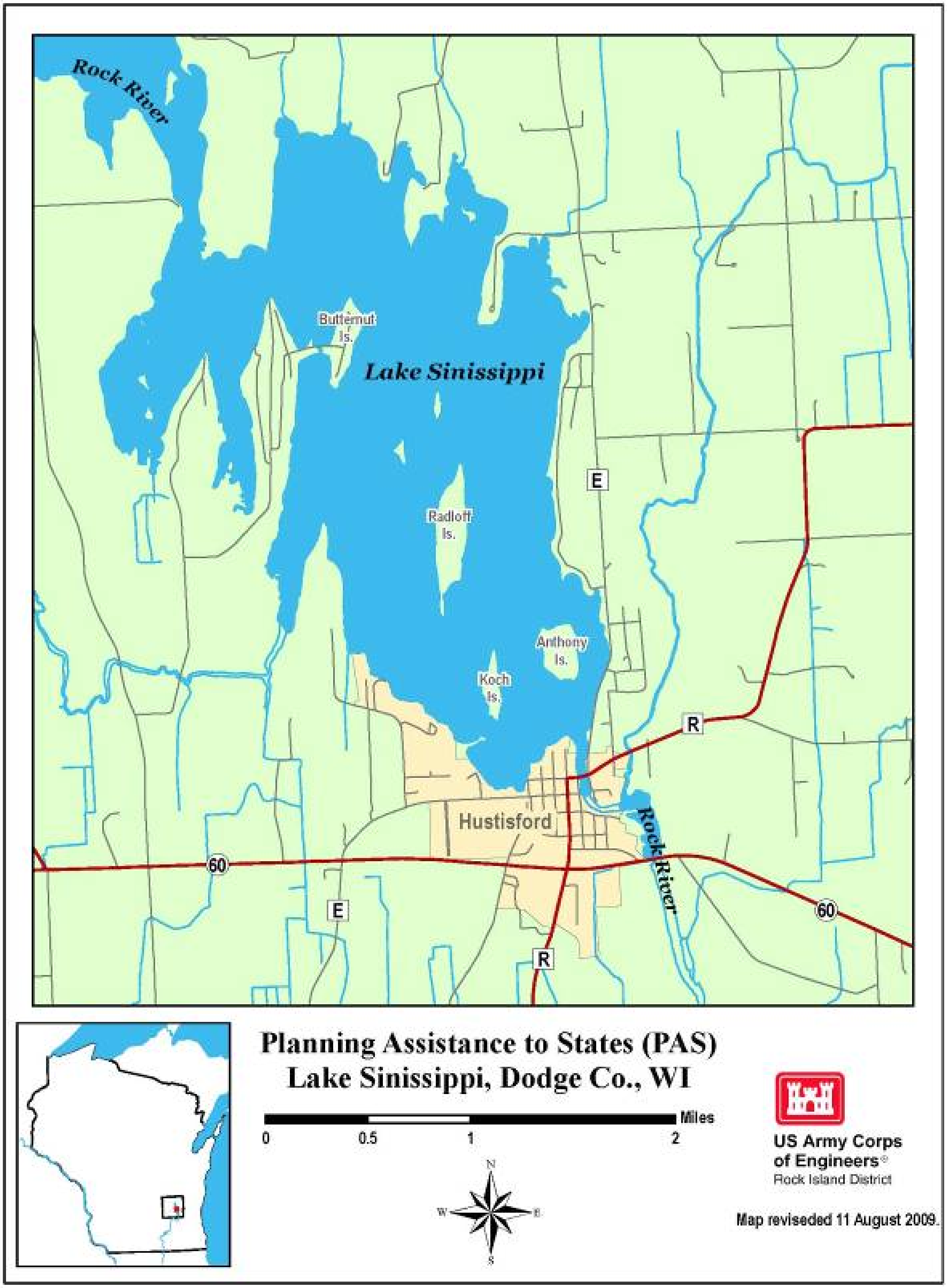


Figure 1. Area Map

Table 1. Physical Characteristics of Lake Sinissippi (July 18, 2005 report Table 1)

Parameter	Lake Sinissippi
Surface Area (open water)	2,855 acres
Watershed Area	511 sq. miles
Watershed to Lake Area Ratio	115:1
Maximum Depth	8 feet
Mean Depth	4.5 feet

Source: Hey and Associates

The lake has been slowly filling in with sediment and the aggraded sediment layer ranges in thickness from 1 to 12 feet. Existing water depths range from 2 to 8 feet with the average depth at 4 to 4.5 feet. A majority of the sediment, 8,606 tons per year, comes from the Rock River and accounts for 90 percent of the sediment load in Lake Sinissippi (Table 3). Dead Creek flows into the west side of the lake and accounts for another 375 tons of sediment per year (4 percent of sediment load). Sediment flows into the lake from other tributaries, shoreline erosion, and atmospheric deposition account for the remaining sedimentation amount.

Sedimentation has impacted recreational boating on the lake, especially in the lower Rock River channel, limiting areas of boating as well as limiting access to the lake, where water depth at boat docks and launches has become too shallow. Sediment deposits in environmentally sensitive areas, such as areas for fish spawning and submergent vegetation, have destroyed wildlife and aquatic habitat. Removing sediment from the lake bottom and river channel would counteract the effects of sediment accretion that impede navigation and degrade the waterway environment.

Table 2. Inflow Volume to Lake Sinissippi from Direct Precipitation
2002 Water Year (September 30, 2003 report Table 5)

Parameter	Volume (acre-feet)	Percent
Inflow		
Direct Precipitation	**7,397**	**2.7**
Rock River at Horicon	**179,238**	**65.0**
Dead Creek	**11,025**	**4.0**
Ungaged Tributaries	**9,050**	**3.3**
Horicon Waste Water Treatment Plant	**590**	**0.2**
Groundwater Inflow	**68,270**	**24.8**
Total Inflow	**275,570**	**100**

Source: Hey and Associates

Table 3. Sediment Inputs to Lake Sinissippi for the 2002 Water Year
(September 30, 2003 report Table 9)

Inflow	Sediment Load (Tons)	Percent of Total
Surface Water Runoff		
Rock River at Horicon	**8,606**	**90.0**
Dead Creek	**375**	**3.9**
Un-gaged Tributaries	**302**	**3.2**
Atmospheric Deposition	**278**	**2.9**
Point Sources		
Horicon WWTP	**4.3**	**0.05**
Juneau WWTP	**1.3**	**0.01**
ClymanWWTP	**N/A**	**N/A**
Total Influent Sediment Load	**9,567 tons/year**	**100.0**

Source: Hey and Associates

Lake islands are experiencing shoreline recession and soil loss due to erosion, which also contributes to the sediment loading to the lake. In 1939, a concrete dam replaced the old wooden dam and raised the water level 1.4 feet to its present elevation. The marshy shoreline of the lake was subject to rapid erosion due to the continuous high water level. Over the past 6 decades, water erosion has caused 4 of the original 12 main islands and shoreland wetlands to disappear.

High nutrient levels, especially those of phosphorus, contribute to excessive algal growth. High turbidity is caused by sediment loading, resuspension by wave and boat action, and stirring up of bottom sediment by carp. Loss of aquatic vegetation is caused primarily by action of the large population of carp. Carp were also an important factor responsible for clearing the lake of submersed and emergent vegetation that covered much of the lake after an extended drawdown in 1972-1973.

Lake Sinissippi, Rock River and Dead Creek are on the Federal 303(d) list of impaired waters due to excessive sedimentation and nutrient enrichment from high levels of phosphorus.

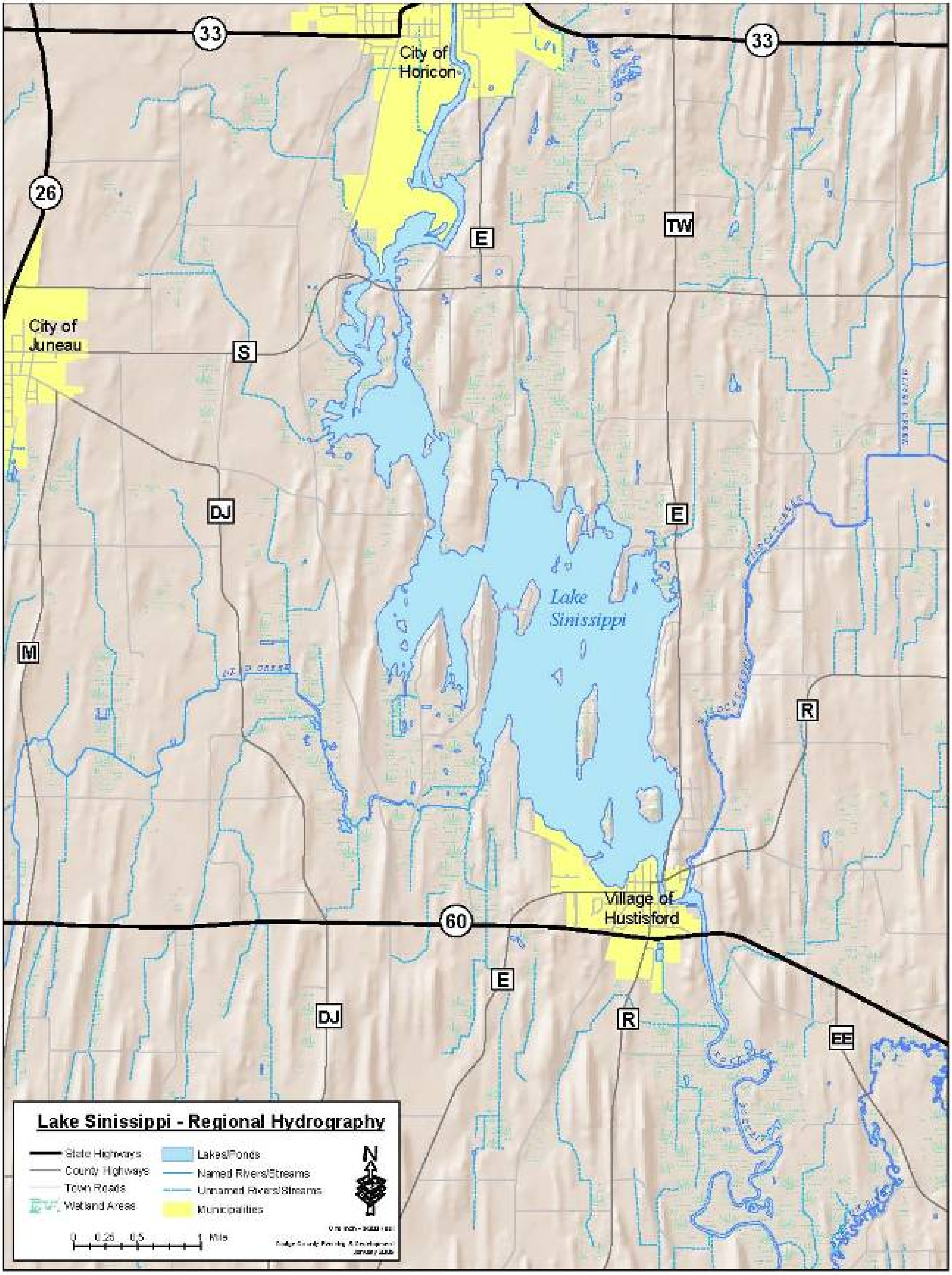


Figure 2. Lake Sinissippi Regional Hydrography Map

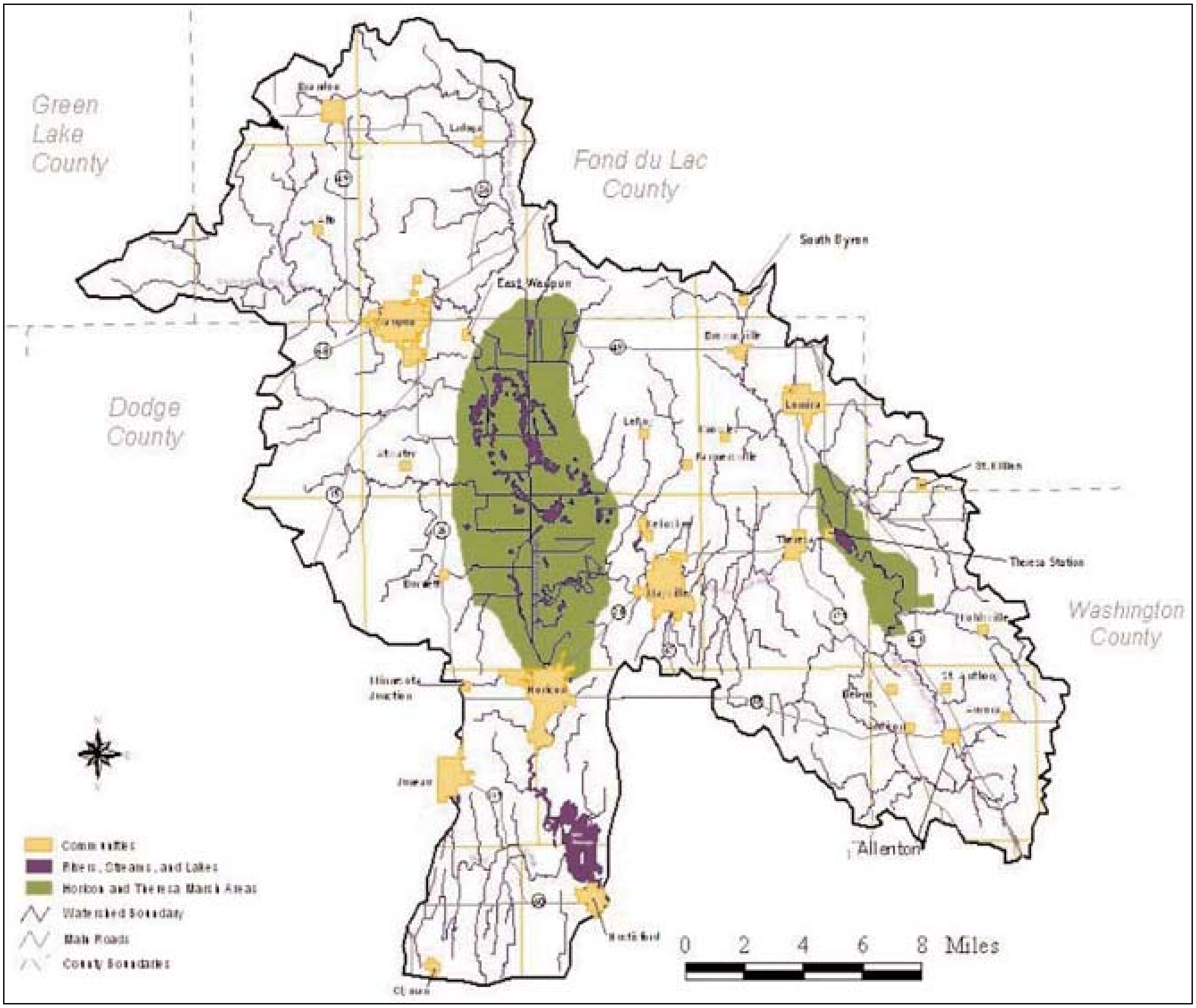


Figure 3. Rock River Headwaters – Lake Sinissippi Watershed

II. PROJECT SCOPE

This study was undertaken to assist the Lake Sinissippi Improvement District (LSID) in developing plans for sediment management, wetland restoration and shore stabilization. This includes identifying potential solutions to reducing sediment depth, sediment flow into the lake, shoreline erosion, and wetland/aquatic plant loss, as well as taking action on opportunities to enhance wildlife and plant habitats.

Sediment is commonly removed from a waterway to improve navigation and restore recreational access for leisure boating, swimming, and fishing. Lake dredging is also done to remove nutrient-rich sediments, lessen sediment resuspension by wind and wave action and improve fish habitat. Removal of lake bed material may also increase the regional flood storage capacity of the lake basin.

Dredging may also improve water quality by reducing the amount of nutrients, such as phosphorus, available from the sediments, thereby reducing nuisance algae blooms. For lakes that freeze over during winter, such as Lake Sinissippi, fish survival can be enhanced by removing high Biochemical Oxygen Demand organic matter within the sediment layer and creating deeper water areas.

Figure 4. Lake Sinissippi Improvement District Office in Hustisford, Wisconsin

The following are four primary goals of the LSID that any proposed restoration alternatives would have to meet.

1. Meet statutory responsibilities to protect and rehabilitate Lake Sinissippi as a lake, without creating severe perturbations to the lake ecosystem that may have serious unintended consequences for the lake community.
2. Be guided by statutory principles to support and enhance recreational uses of the lake to satisfy the needs of the local community and other recreational users.
3. Maintain existing shoreline using natural materials wherever possible and restore emergent marsh and aquatic plant habitat within littoral zone of lake and near-shore areas of river.
4. Create a lake basin and environmental characteristics to support future development of viable balanced fisheries.

Alternative management and technical methods to develop viable balanced fisheries are not addressed as part of this scope of work.

The LSID conducted several samplings of sediment depth measurements. Depth measurements were recorded for depth of water to the surface of sediment, and then for the depth to hard pan, which allowed for the determination of sediment depth by difference. Depth measurements were utilized to create bathymetry mapping of the lake bottom, indicating depths of the sediment layer. The LSID also provided mapping, data, and contacts for technical assistance to the U.S. Army Corps of Engineers (Corps) to develop the maps included with this report, labeled as Plates 1 through 10, located in Appendix C.

III. SEDIMENTATION

Sediment has been entering the lake since the lake was created as an impoundment in 1845, when a dam was built in Hustisford. The average depth of sediment is 2.3 feet, while the average water depth is 4 – 4.5 feet with a surface water elevation of 855.5. The sediment is typically a fine soil made up mostly of clay particles, loose silt, and organic matter. A majority of the sediment has likely come from agricultural fields in the watershed and is a great natural resource to be utilized again, if possible. The sediment in Lake Sinissippi is good for raising crops and can be applied to agricultural fields or gardens.

In 2003, the LSID conducted a survey of the lake bottom to measure water depths and sediment depths. Sediment depths were measured by pushing a rod from the top of the sediment to the hardpan and measuring the distance between the top of the sediment layer and the hardpan. Over 3,000 data points were collected and this information was forwarded to Mapping Specialists in Madison, Wisconsin, to develop bathymetry maps. Plates 1 and 2 in Appendix C, provided by Mapping Specialists, indicate water depth and depth to hard pan, respectively. In 2008, the LSID conducted a second survey of 120 data points, sampling water depths and sediment depths to determine the distribution of sediment and the depth of sediment changes since 2003. Plate 3 in Appendix C shows the changes in sediment as measured in 2008, overlaid onto the 2003 map. Comparing the data of 2003 and 2008 indicates that sediment has increased in the areas of Lower Rock River Channel, Steffen Point, and Dead Creek. Other areas stayed relatively the same. Plate 4 was developed utilizing the depth information gathered by the LSID to show water depths if sediment were removed to allow for a 5-foot water depth. Areas in green on Plate 4 indicate water depths of less then 5 feet due to the hardpan that is located above elevation 850.5. Two areas in red indicate water depths that are currently deeper then 5 feet, and would require no dredging to achieve a 5 foot water depth.

No specific projects - including detailed plans and specifications - are identified as a part of this study. However, to assist the LSID in future planning efforts, the lake was separated into 23 different areas to calculate sediment volumes (Table 4 and Plate 5 in Appendix C). These areas indicate where potential projects might occur, and the quantity of sediment in those areas. The ArcGIS Desktop software made by ESRI, used to calculate these quantities, can be easily modified to indicate various desired depths of dredging. Because it is unlikely that a large area would be dredged entirely to hard bottom, 5 feet was chosen as an arbitrary starting point to calculate sediment quantities. This depth will allow for most navigation and recreational boat use on the lake. Quantities were also estimated for dredging depths of 5 feet, 10 feet and to hard pan. All volumes were calculated as in situ volumes and no adjustments were made to account for moisture content. Sediment samples taken from the lake in 2003 indicated an estimated solids content of 97 to 99 percent.

The 5-foot dredging depth is the depth of water based on a water surface elevation of 855.5. In areas where the hard pan is above 850.5, the software adjusted estimates so that only the amount of sediment in the area was included, and material deeper than hard pan was not included in the quantity estimates. The 5-foot depth estimate is the volume of sediment inside the indicated area on Plate 5 and includes vertical sides without slopes.

The environmental sites are based on 10-foot depths, which would allow for overwintering habitat for fish. The volume estimate is calculated on dredging a 10-foot deep hole inside the area indicated on Plate

6 with vertical sides. It is estimated that after dredging these environmental sites, the vertical sides would slump to approximately 4:1 slopes. The environmental sites are the only sites where 10-foot depths were estimated. The total volume estimate is based on dredging to hard pan, essentially removing all sediment inside the indicated areas shown on Plate 5. Note that the total volume estimate in Table 4 is for the indicated areas only and does not include the entire lake surface area. A separate estimate for complete removal of all lake sediment from Highway S to the Hustisford Dam is estimated at 10,668,000 Cubic Yards (CY).

Volume of dredging in the Upper and Lower Rock River Channel was estimated by assuming a 100-foot wide channel, 5-foot deep with vertical sides. Vertical side slopes will be less complicated for the contractor to dredge and a majority of the sediment being dredged in this section is 2–3 feet thick so the sloping of the sides is not necessary. Another reason for keeping sides vertical is that this will allow for safer navigation as boaters will have plenty of room to pass on the channel.

Uses for this sediment and methods of removal are addressed next.

Table 4. Dredging Sites Area and Volume

Dredge Site	Area Acres	Volume CY 5-ft depth	Volume CY 10-ft depth	Volume CY To hard pan
1. Anthony Island East	43.0	102,000		239,000
2. Anthony Island West	71.9	107,000		258,000
3. Neider Park	38.7	119,000		149,000
4. Lake Drive South	251.9	236,000		1,016,000
5. Koch Island	103.9	110,000		237,000
6. Radloff Island	195.1	208,000		646,000
7. Lake Drive North	186.7	177,000		977,000
8. Stone Island	196.6	123,000		651,000
9. Dead Creek	104.7	235,000		262,000
10. Stone Island Environmental Site	12.9		99,000	63,000
11. Wildcat Road	37.5	65,000		80,000
12. Kinkel Point	116.9	116,000		572,000
13. Wild Cat Road Environmental Site	19.1		161,000	133,000
14. Radloff Point Islands	93.8	129,000		389,000
15. Public Hunting Grounds	115.3	216,000		541,000
16. Sam Point	88.6	195,000		497,000
17. Butternut Causeway	37.1	62,000		68,000
18. Steffen Point	80.0	235,000		459,000
19. Spearhead Road	57.5	169,000		203,000
20. Eagle Island	96.0	267,000		417,000
21. Lower Rock River Channel	23.4	64,000		151,000
22. Upper Rock River Channel	14.2	18,000		45,000
23. Lower Rock Environmental Site	8.5		99,000	64,000
Total		3,312,000	259,000	8,117,000

A. SEDIMENT PLACEMENT

Maintenance dredging is an ongoing task that will require numerous placement sites. When looking for placement sites, consideration should be given for a long-term solution to maintain the ability to place sediment well into the future. Sediment placement sites take on many considerations, such as proximity to the dredging area, topography of the site, land cover of the site, cost to deliver sediment, end use of the sediment, and how the sediment will be delivered to the site. There are several opportunities for placement of the sediment from Lake Sinissippi, which include both upland and in-lake placement. Both types of placement offer the advantages of beneficially using the dredged sediment and both types are described in more detail.

To a lesser extent other options might include bankline placement and confined placement of dredged material. Moderate use of carefully selected bankline sites with appropriate control measures may be an option for limited dredging events. Confined placement may be an option if dredged solids need to be retained with controlled release of ponded water from the containment area.

The predominate sediment found in Lake Sinissippi is fine silt and clay. This type of material has many potential uses, as indicated in Table 5. Beneficial use is the productive use of dredged material by the public or private sources.

Table 5. Dredged Materials and Potential Beneficial Uses

	Dredged Material Sediment Type				
Beneficial Use Options	**Rock**	**Gravel & Sand**	**Consolidated Clay**	**Silt/Soft Clay**	**Mixture**
Engineered Uses					
Land creation	x	x	x	x	x
Land improvement	x	x	x	x	x
Berm creation	x	x	x		x
Shore protection	x	x	x		
Replacement fill	x	x			x
Beach nourishment		x			
Capping		x	x		x
Agricultural/Product Uses					
Construction materials	x	x	x	x	x
Aquaculture			x	x	x
Topsoil				x	x
Environmental Enhancements					
Wildlife habitats	x	x	x	x	x
Fisheries improvement	x	x	x	x	x
Wetland restoration			x	x	x

Source: (from http://el.erdc.usace.army.mil/dots/.html) Dredging Operations Technical Support Program, Beneficial Uses of Dredged Material, US Army Corps of Engineers, Engineer Research and Development Center, Research Laboratory

Some of the potential beneficial uses of the fine silt/clay sediment in Lake Sinissippi include:

Land Creation: Land creation using dredged material includes filling, raising, and protecting an area that is otherwise periodically or permanently submerged. It also includes island creation, or the re-establishment of lost islands that would provide for enhanced wildlife habitat on Lake Sinissippi.

Land Improvement: Dredged material may be used for land improvement when the quality of existing land is not adequate for a planned use, or where the elevation of the land is too low to prevent occasional flooding. Dredged material of fluvial origin is primarily eroded topsoil and organic matter that may be used on agricultural land to improve the soil structure. Potential applications in the area of Lake Sinissippi include dairy and arable farming, recreation areas, playing fields, golf courses, parks, light residential development or light commercial storage areas.

Wildlife Habitats: Dredged material can be used beneficially to enhance or create various wildlife habitats. This may be either incidental to the project purpose or planned. For example, nesting meadows and habitat for large and small mammals and songbirds have been developed on upland or floodplain (seasonally flooded) dredged material placement sites. Numerous examples are available where dredged material has been used to create nesting islands for waterbirds and waterfowl.

Fisheries Improvement: Creation of shallow areas that provide plant growth and habitat for fish cover. Appropriate placement of dredged material can improve ecological functions of fishery habitat. Fishery resource improvement can be demonstrated in several ways. Bottom relief created by mounding of dredged material may provide refuge habitat for fish.

Wetland restoration: Dredged material has been extensively used to restore and establish wetlands. Where proper sites can be located, and government and private agency cooperation can be coordinated, wetlands restoration is a relatively common and technically feasible use of dredged material.

Wetlands restoration or rehabilitation using dredged material is usually a more acceptable alternative to creation of a new wetland. Many of the world's natural wetlands are degraded or impacted, or have been destroyed, and the recovery of these wetlands is more important than creation of new ones. Most former wetlands still have hydric soils, even though the hydrologic characteristics of the site may have been altered. When a new wetland is created, hydric soil conditions, appropriate hydrologic conditions, and wetland vegetation must all be introduced to the site. Creation of a new wetland would also mean replacing one habitat type with another, which is not always desirable. Long-term planning, design, maintenance, and management are necessary to maintain a created wetland.

Wetland restoration using dredged material can be accomplished in several ways. For example, dredged material can be applied in thin layers to bring degraded wetlands up to optimal aquatic plant growing water depths. Dewatered dredged material can be used in wind and wave barriers to allow native vegetation to regrow and restore the viability of a wetland. Dredged material sediment can be used to stabilize eroding natural wetland shorelines or nourish subsiding wetlands. Dewatered dredged material can also be used to construct erosion barriers and other structures that aid in restoring a degraded or impacted wetland.

Sediment compositional analysis: On July 24, 2003, MVR Water Quality and Sedimentation Section (ED-HQ) personnel collected sediment samples from six locations as part of the Lake Sinissippi Section 22 project. See Plate 7 Appendix C titled (Figure 1: Lake Sinissippi Sediment Sample Locations) for locations of the six samples taken. Locations were pre-determined based on likely project feature descriptions from LSID board members and located on-site using GPS. Three of the sites were in Lake Sinissippi: LS4 behind Anthony Island, LS5 at the mouth of Dead Creek, and LS6 off the east side of Radloff Island. The other three locations were in the channel/marsh areas upstream of the lake: LS1 immediately downstream from the Highway S Bridge; LS2 in the Horseshoe Road area to the right of the channel; and LS3 at the mouth of a small tributary. Samples were collected with a 48-inch long, plastic-lined, stainless steel core sampler. Each sample was a composite, consisting of at least two subsamples collected within a few feet of each other. Each sediment core was placed in a stainless steel bowl, mixed to form a homogenous sample, and then placed into separate sample bottles for chemical and grain size analyses. Ambient water samples were collected at each site for settleability tests. As a quality control measure, a duplicate sample was collected at site LS4. All samples were stored in an ice chest and packed with ice to remain below 4 degrees Celsius. Access to the sampling locations was facilitated by the use of an airboat due to the shallow nature of the lake.

Grain size analyses were performed on all sediment samples by MVR Geotechnical Branch (ED-G) personnel in accordance with EM 1110-2-1906. Bulk sediment and ambient water samples were shipped to Davy Laboratories of La Crosse, Wisconsin, for chemical analysis, according to U.S. Environmental Protection Agency and Standard Methods.

The percent finer than #200 sieve values ranged from 25.3 percent at site LS1 (bed material in the main channel) to 94.8 percent at site LS4 (backwater area behind Anthony Island). Most of the samples were mostly clay, with high organic material content. Sites LS1 and LS5 had less fine grained material, with more sand than the other locations.

Values for chemical toxicity parameters indicate that sediment material from the proposed dredge cuts is non-hazardous and should meet standards of Wisconsin Chapter NR 504.04(4) and be acceptable for upland placement.

For in-water placement of dredged material, the guidelines for threshold effect concentration indicate that cadmium concentrations found at four sites could potentially have adverse effects on benthic organisms. The use of a confined placement area or other precautions to retain suspended material might be necessary to minimize possible water quality impacts. Pumping sediment into geotextile containers for breakwater containment areas and use of dredged material as fill for island enhancement and wetland restoration are several methods for in-lake confined placement. Also, the LSID might investigate the solubility characteristics of cadmium compounds in sediment under conditions of pH, oxygen content, and redox potential likely to be found at potential in-lake placement sites.

1. UPLAND PLACEMENT

Upland placement is typically defined as the placing of material up and out of the water on dry ground, where it can be placed permanently or used beneficially. Since the sediment in Lake Sinissippi is a quality resource that is valuable for producing crops, this material can be utilized effectively by local farmers and gardeners. A placement site designed for beneficial use would allow for land access to the site, where material could be loaded and hauled away. Being able to haul material away is important for LSID in order to maintain long-term maintenance dredging abilities, because none of the potential sites identified offers long-term, repeated placement if the material is not removed. Potential upland placement sites indicated on Plate 6 were arbitrarily picked as having potential for placement because they appear to be open areas, are close to the lake so that they could be reached by hydraulic and mechanical placement methods, and they are close to road access for removal of material. See Table 6 for a listing of potential upland placement sites and estimated acreages.

There are two methods of delivering sediment to upland sites: hydraulic and mechanical dredging (in some cases a project may require a combination of dredging methods). Both of these methods are described in further detail.

Table 6. Potential Upland Placement Sites

Site	Acres	Max Elevation	Min Elevation	Ave. Elevation	*Capacity Estimate CY
A	27	877	857	867	130,680
B	11	874	857	864	53,240
C	85	952	858	888	411,400
D	50	903	859	877	242,000
E	22	878	858	868	106,480
F	12	874	859	866	58,080
G	8	879	859	872	38,720
Totals	215				1,040,600

***Strictly for illustration of the magnitude of the area needed for upland placement. These are not actual capacities of the sites listed. These capacity estimates are based on 3-foot berms, flat placement sites and the area of the berms themselves is not taken into account, which further reduces the actual capacity. Since these sites are not flat and have steep slopes, the actual capacity of these sites is significantly less.**

a. HYDRAULIC DREDGING

Hydraulic dredging is a method that utilizes a cutter and a pump to suction sediment and water, which, when combined, form slurry. The pump moves the slurry to the designated placement site. The slurry is pumped through a pipeline which can vary in diameter and extend up to several thousand feet or more. There are many options in pipe size, length, and pumping capacity available to handle varying consistencies of sediment, sediment location, and final delivered location. (See Figures 5 and 6) The key factors to consider are the type of sediment to be pumped, the distance from the current location to the placement site, the elevation difference of the placement site from the current location, and size of the dredge.

Figure 5: Horizontal auger hydraulic dredge with cable winch – 174 Hp diesel engine with 10-inch diameter discharge pipe.

Upon reviewing the topography surrounding Lake Sinissippi, it was discovered that most of the available open areas that are not wetlands range from fairly hilly to steep slopes. For example, proposed potential placement sites C (to the north) and A (to the south), are farm fields with fairly steep slopes. The steep slopes and high elevations above the lake combine to reduce the amount of material that can be effectively pumped to these sites. Hydraulic placement of the fine sediments in Lake Sinissippi will also require large containment areas to be constructed in order to contain the sediment and water that is pumped. Table 7 shows that dredging 3,000 CY of sediment requires a placement site that can contain a volume of at least 37,500 CY. This volume would require an 8-acre site with 3-foot high berms, depending on whether the site was flat. Since the placement sites proposed are very sloped in nature, the containment berms required to contain 3,000 CY of sediment with water would be extremely high and require a larger berm base. Constructing berms on a steep slope is normally not cost effective construction because a large, deep berm would only contain a sediment quantity from a minimally-sized dredging event.

Table 7. Potential Upland Placement Site Capacities For 3,000 CY Events

Berm Height	Area Inside Berm (ft^2)	Area Inside Berm (ac)	*Volume Inside Berm (cy)
3 ft	348,480	8.0	37,500

***Volume includes 3,000 CY sediment, water, and 25% factor of safety (10% solids, 90% water)**

To illustrate another point emphasizing the lack of volume in upland placement sites available around Lake Sinissippi, the total capacity of all sites identified on Plate 6 combined, assuming 3-foot high berms and non-sloping containment areas, would be 1,040,600 CY. This is far short of the estimated 3,312,000 CY of sediment currently in the lake to the 5-foot depth. At the same time, there will be more sediment to come. Table 6 lists potential upland placement sites along with their acreages and average elevation. Since these sites are not flat and tend to slope significantly, the actual capacities shown in Table 6 are overestimated and are used only to illustrate that there is limited capacity for upland placement. There is not enough field data of the potential upland placement sites available for this planning effort to accurately estimate placement capacities for these sites. This condition of limited placement sites and storage volume, along with associated high land values, underscores the importance of maximizing in-lake placement and reuse of sediment wherever possible.

Another factor to consider with hydraulic dredging is the distance from the dredge site to the placement site and the elevation difference between the dredge site and placement site. Table 8 indicates average rates of dredging volume for certain size dredges and length of pipe used when pumping material to a height of 20 feet or less.

Table 8. Production Rates for Hydraulic Dredges

Dredge Size	Assumed Pump Horsepower	Hourly Production Rate (cubic yards per hour with 2000' pipe length)	Hourly Production Rate (cubic yards per hour with 4000' pipe length)	Hours Required to Dredge 3000 CY
8"	375 HP	150	125	24
10"	500 HP	200	130	23
12"	700 HP	270	180	17

NOTES:
1. Table based on ER 1110-2-1300
2. Dredges can pump distances in table with 20' of lift. If higher lift is required, length of pipe should be reduced, or production rates will decline.
3. Production rates can vary dramatically based on material being dredged, depth of material being dredged, experience of dredge crew, etc.

Figure 6: Hydraulic cutter dredge with 8-inch diameter discharge pipe – 2 hydraulic spuds – 200 Hp diesel engine with clear water pumping capacity of 600-900 CY per hour – 44 feet in length with maximum draft of 2.5 feet.

The LSID used hydraulic dredging of 3,000 CY of sediment from the lake bed to construct the Geotube® geotextile containment breakwater in 2006. The dredger/pumper used a cutterhead dredge with a 150-hp pump and 8-inch transport pipes. The nominal pumping rate was 1,000 gallons per minute, running at about 12 percent solids. The production rate was about 0.5 CY per minute or 30 CY per hour (on a dry basis), translating to 100 hours to dredge 3,000 CY of sediment. The dredging cost was approximately $10 per CY.

An alternative that the LSID might consider is to find a location nearest to the priority dredging sites that is relatively flat to construct a containment area. The containment area should have land access so that material can be hauled off to be spread on fields or used/sold for other uses.

Containment Berms: Containment berms for hydraulic dredging would typically be constructed of native soils at the placement site if the soils consist of mostly clay particles. Berms should be constructed with a top width of 5 feet and side slopes of 3:1. Figure 7 shows the cross section of a typical containment berm that could be constructed for hydraulically placed material. The berm should also have additional height to account for a factor of safety, in case the volume of material pumped exceeds the design amount, and to protect from overtopping if there is excessive wind action on the water in the containment site. Due to the fine sediment in the lake, settling time for the particle to fall out of suspension could take up to one day. After that time, water in the containment area could be pumped back to the lake or allowed to flow back to the lake through a weir. Again, due the fine sediments and settling time required, a weir would have to be constructed so that water would be released only after the settling of particles had been completed.

Another option to consider when using containment areas would be to construct a silt fence across the corner of the containment area using filter fabric and straw bales. It is possible that water from the slurry could filter through the silt fence and allow for clean water to be pumped back to the lake. If water could be pumped back to the lake during dredging operations, more material could be dredged as the containment site would have more capacity when water is filtered off and pumped to the lake.

Hydraulic dredging varies in cost depending on the depth of sediment, distance and height to placement site, size of containment area and type of sediment being pumped, as well as other contract issues and mobilization. Hydraulic dredging generally ranges between $12 and $16 per CY. Table 9 indicates the estimated costs for hydraulically dredging each of the proposed priority dredge sites.

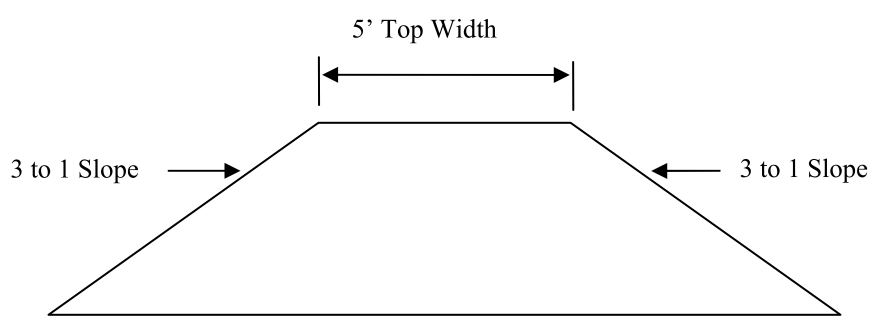


Figure 7. Containment Berm

Table 9. Dredging Sites, Dredging Methods, Priority and Cost

Dredge Site	Dredge Method	Estimated Volume CY	Cost/CY	Estimated Cost Millions
1. Anthony Island East	Hydraulic	102,000	$12-$16	$1.2 - $1.6
2. Anthony Island West	Hydraulic	107,000	$12-$16	$1.3 - $1.7
3. Neider Park	Hydraulic	119,000	$12-$16	$1.4 - $1.9
4. Lake Drive South	Hydraulic	236,000	$12-$16	$2.8 – $3.8
5. Koch Island	Hydraulic	110,000	$12-$16	$1.3 - $1.7
6. Radloff Island	Hydraulic	208,000	$12-$16	$2.5 - $3.3
7. Lake Drive North	Hydraulic	177,000	$12-$16	$2.1 - $2.8
8. Stone Island	Hydraulic	123,000	$12-$16	$1.5 - $2.0
9. Dead Creek	Hydraulic	235,000	$12-$16	$2.8 - $3.8
10. Stone Island Environmental Site	Hydraulic	99,000	$12-$16	$1.2 - $1.6
11. Wildcat Road	Hydraulic	65,000	$12-$16	$.8 – $1.0
12. Kinkel Point	Hydraulic	116,000	$12-$16	$1.4 - $1.9
13. Wild Cat Road Environmental Site	Hydraulic	161,000	$12-$16	$1.9 - $2.6
14. Radloff Point Islands	Hydraulic	129,000	$12-$16	$1.5 - $2.1
15. Public Hunting Grounds	Hydraulic	216,000	$12-$16	$2.6 - $3.5
16. Sam Point	Hydraulic	195,000	$12-$16	$2.3 - $3.1
17. Butternut Causeway	Hydraulic	62,000	$12-$16	$.7 - $1.0
18. Steffen Point	Hydraulic	235,000	$12-$16	$2.8 - $3.8
19. Spearhead Road	Hydraulic	169,000	$12-$16	$2.0 - $2.7
20. Eagle Island	Hydraulic	267,000	$12-$16	$3.2 - $4.3
21. Lower Rock River Channel	Hydraulic	64,000	$12-$16	$.8 - $1.0
22. Upper Rock River Channel	Hydraulic	18,000	$12-$16	$.2 - $.3
23. Lower Rock Environmental Site	Hydraulic	99,000	$12-$16	$1.2 - $1.6

Table 10. Priority Order of Dredging Sites (Hydraulic Dredging)

Priority	Dredge Site	Estimated Volume CY	Cost/CY	Estimated Cost Millions
1	21. Lower Rock River Channel	64,000	$12-$16	$.8 - $1.0
2	18. Steffen Point	235,000	$12-$16	$2.8 - $3.8
3	9. Dead Creek	235,000	$12-$16	$2.8 - $3.8
4	19. Spearhead Road	169,000	$12-$16	$2.0 - $2.7
5	20. Eagle Island	267,000	$12-$16	$3.2 - $4.3
6	17. Butternut Causeway	62,000	$12-$16	$.7 - $1.0
7	14. Radloff Point Islands	129,000	$12-$16	$1.5 - $2.1
8	11. Wildcat Road	65,000	$12-$16	$.8 – $1.0
9	3. Neider Park	119,000	$12-$16	$1.4 - $1.9
10	1. Anthony Island East	102,000	$12-$16	$1.2 - $1.6
Total		1,447,000		

It should be noted that these costs would increase depending on how far away the sediment is being placed. There are limited upland sites that could be used for hydraulic placement, but not every area to be dredged is within close reach of the placement site. For example, dredging area 10, Anthony Island East, is approximately 6,750 ft away from placement site A and 6,000 ft away from placement site G, as indicated on Plate 6. Placement site A has an estimated capacity of 130,680 CY, and placement site G has an estimated capacity of 38,720 as shown in Table 6. In addition, Neider Park dredging area 3 is in similar proximity to Anthony Island East and would need more placement site capacity then Anthony Island East.

There are, however, methods available to address long distances from dredge site to placement site at additional cost. Two methods of accomplishing this would be using booster pumps, or double handling material. Double handling material involves pumping to a location on the lake, moving the dredge, and pumping the same material again. These are options that can be considered with a dredging contractor, as there are many variables involved with any dredging operation.

b. MECHANICAL DREDGING

Mechanical dredging for upland placement on Lake Sinissippi poses a challenge due to the shallow water depths. Typically mechanical dredging is performed from a barge requiring a minimum draft of 2 feet when empty and 6 feet when full. A floating excavator as seen in Figure 6 is a normal hydraulic excavator with a different undercarriage that gives the excavator a very low ground pressure. This very low ground pressure allows the excavator to work in marsh/wetland type environments where a normal excavator or typical dredge cannot reach. An option that has been witnessed by Corps staff operating in the Henderson Drainage and Levee District in Illinois is to mount an excavator on pontoons, allowing for a draft of 1 to 1.5 feet. This operation was performed by side casting the material and no material was loaded onto barges due to the shallow depth. However, this could work for Lake Sinissippi as an excavator could be used to move material multiple times until a placement site has been reached.

Figure 8: Floating Excavator As stated previously, floating excavators are ideal for those hard to reach places and are highly mobile. However, they are not as efficient as the other types of machines.

Mechanical placement typically utilizes a barge to move material from the dredge site to the placement site. Again, this process of barging material would not be effective in the shallow waters of Lake Sinissippi. An option that could be pursued is the use of concrete pumps in series. The dredged material could be scooped with an excavator on pontoons and placed in a hopper, where the high solids content material could be pumped. Typical pumping distances for concrete pumps range from 500 to 1,500 feet. Another option would be the use of hydraulic pumps in series, and utilizing a concrete pump as the last pump so that high solids would be pumped to the final placement site and water could remain in the lake.

An additional method of mechanical dredging is to lower the water level to allow access for construction equipment to operate on the lake bed in order to remove the sediment. Dredging exposed lake bed sediments could occur during either drying or freezing conditions. Conventional excavation equipment such as backhoes, scrappers or bulldozers could work from shore or move onto the dewatered lakebed. This can also be done in small areas by installing sheet pile and pumping water out of the enclosed area. Then when the sediment dries, construction equipment can be operated in the contained area to remove the sediment.

Mechanical dredging could be preferred over hydraulic dredging when placement of material will be in geotextile containers for island creation. Mechanical dredging allows for a higher content of solids, compared to hydraulic dredging that would then be pushed and pumped into the containers for a better fill. Backhoes, draglines, clamshell, and grab buckets could operate from shore or on floating barges and pontoons, depending on the restrictions due to shallow water depth.

Mechanical dredging varies in cost depending on the depth of sediment, equipment used, distance to placement site as well as other contract issues and mobilization. Generally, mechanical dredging will range between $8-13 per CY.

Wet mechanical dredging may cause sediment resuspension and turbidity at the construction site. The potential consequences to water quality and aquatic habitat downstream need to be considered in any restoration plan. Due to the shallow nature of Lake Sinissippi, it may be possible to contain re-suspended silt by using a silt curtain.

The LSID utilized mechanical dredging in two smaller sediment removal projects. The first project, in 2007, removed 1,000 CY of sediment from a large agricultural ditch that empties into Dead Creek just prior to the confluence with the lake. The sediment was incorporated within an upland farm field. In 2009, a second project removed 3,000 CY of sediment from Dead Creek near St. Helena Road and incorporated the sediment within an upland farm field (Figure 9). Both projects were done using a long-reach backhoe, positioned at the shoreline. The cost of excavation including mobilization, permits, sediment analyses, and site restoration was about $2.50 per CY.

Figure 9. Mechanical dredging with long-reach backhoe at Dead Creek February 2009

2. IN-LAKE PLACEMENT

Several in-lake sediment placement locations are proposed as environmental enhancement sites as shown on Plate 6 in Appendix C. These sites would increase plant and wildlife habitat like the completed test project site (site 6 on Plate 6) at Wildcat Road, while at the same time providing for beneficial use of lake sediment. Three island sites that would increase habitat for shoreland and terrestrial wildlife are also included. The proposed island sites labeled as 2, 3 & 7 on Plate 6 are located where islands existed in the past and have eroded away over the last 30–50 years. Figure 10 shows a 1950 aerial view of the islands located to the northeast of Lehman's cottages on the Rock River, which is an example of islands that have been lost on Lake Sinissippi. For reference, the location of the islands shown in Figure 10 would have been located near Site 13 on Plate 6. A map of lost wetlands, emergent vegetation, and islands is included on Plate 8 Appendix C.

For island sites such as sites 2, 3 & 7, Geotubes, or other sediment-filled revetments, could be used to construct an outer ring to contain sediment that would be pumped inside the ring to form the island. Sediment could be placed to an elevation of 1-foot above surface water to form the island. Back water enhancement sites would be constructed in the same way as the project at Wildcat Road, using a geotextile containment tube as a barrier to protect and hold sediment back for the development of shallow water aquatic plants. Estimates for sediment placement behind containment breakwaters are based on a 1-foot depth of water to enhance plant growth. Table 11 indicates the potential in lake/environmental enhancement sites and their estimated placement quantities.

Another in-lake placement that could be considered is related to shoreline protection, which is mentioned in section B-2.

Table 11. In-Lake Environmental Enhancement Placement Sites

Area	Name	Geotube Berm Length (ft)	Surface Area (ac)	Volume in Geotube, 3-ft (cu-yd)	Volume in Geotube, 5-ft (cu-yd)	Volume Behind Berm (cu-yd) Available Below Elevation 854.5 ft
1	Dead Creek Mouth	2,122	11.2	1061	4032	4,900
2	Lost Islands	1,897	6.2	*2846	*1082	26,400
3	Stone Island	1,347	3.3	*2021	*7678	12,600
4	Spearhead Road	1,396	6.9	698	2652	100
5	Wildcat Road	3,187	45.1	1593	6055	107,500
6	Geotube Pilot Site	581	29.2	291	1104	49,800
7	Radloff Point Islands	3,285	16.7	*4298	*18725	44,600
8	Radloff Point	654	14.0	327	1243	19,700
9	Public Hunting Grounds	1,515	30.5	758	2879	41,600
10	Ox-bow Berm/Jetty	4,418	11.8	2209	8394	24,300
11	Eagle Bay	1,839	16.2	920	3494	4,900
12	Hillview Lane	1,734	15.6	867	3295	22,800
13	Lehman's Point	6,448	120.0	3224	12251	147,800
14	Saint Helena Road	1,304	15.7	652	2478	2,900
15	Upper Rock C	1,249	4.2	625	2373	2,600
16	Upper Rock B	652	19.3	326	1239	16,800
17	Bennetts Road	1,207	9.0	604	2293	10,700
18	Upper Rock A	623	5.7	312	1184	0
Total		35,458	380.6	23,632	82,451	1,576,000

***Assumes a perimeter of 3 berms to construct the island.**

Figure 10. 1950 photo of islands near the Lower Rock River area overlooking Lehman's cottages, to NE. or area 13 on Plate 6

Of the potential enhancement sites listed in Table 11, sites 1, Dead Creek Mouth, 10, Ox-bow and 13, Lehman's Point, are considered by the LSID as three of their top priority project sites. All three sites are located in the vicinity of inflows from the Rock River and Dead Creek which are the major contributors to sediment inflow. These areas are also key concern areas due to the loss of wetlands and the widening or departure from the original channel of the incoming streams.

Lehman's Point and Dead Creek Mouth are proposed enhancement sites utilizing Geotubes as a barrier. One of the concerns with Lehman's point is that the Rock River has left its main channel in this area and flows much wider and shallower. The large peninsula and islands that existed in the past along the left descending bank of the river, as shown in Figure 10, have disappeared. Several options are proposed to enhance Lehman's point labeled as area 13 on plate 6. The main focus of the proposed options is to maintain the original channel of the Rock River to enhance a navigable channel and enhance opportunities to create lost wetland habitats and islands.

Option 1 is similar to the other proposed enhancement sites where a Geotube berm is used to protect an area of lost aquatic habit and wetlands. The Geotube berm that is filled with sediment from the lake serves as a barrier between the lake and the wetland. No sediment would be placed behind the berm with Option 1 as is proposed in other enhancement areas. There is a large area in the middle of Site 13 that currently has a water depth of 1-foot (bottom elevation of 854.5) as indicated on Plate 9. The benefit of this option is that sediment from the Lower Rock River could be beneficially used to construct a berm that would protect aquatic plants behind the berm while at the same time constraining the flow of the Lower Rock River to its original channel. By keeping the incoming flow of water in the original channel, the channel would tend to be self-scoured, therefore reducing the need for dredging to keep a navigable channel open in this area.

Option 2 calls for the placement of sediment inside the bermed area formed by Option 1. Approximately 147,800 CY of sediment from the lake would be beneficially used to decrease the depth of water inside the berm to 1-foot, which will allow for enhanced conditions to grow aquatic and wetland plants.

Option 3 focuses on the concept of maintaining the original channel. Geotube berms as shown on Plate 10 would be utilized to form a barrier along the original channel alignment keeping a majority of the incoming flow in the original channel. This would help navigation in this area as more flow in the channel would tend to keep the channel scoured, reducing the need for dredging. The area behind the berm would tend to silt in more as water would slow down and drop its sediment load. Aquatic plants could be established behind the berm in the shallow water areas. However, the Geotube berms in this option would not be continuous or form a complete barrier. The berms would be 100-foot long Geotubes with 100-foot long gaps between the Geotubes allowing for some navigation into area 13.

Option 4 focuses on the concept of maintaining the original channel by recreating some of the lost islands near Lehman's Point. The islands would be constructed by utilizing Geotube berms for their perimeter and filling the inside of the berm with sediment to form the island. The islands would be aligned as shown on Plate 11 to form a barrier that would help to keep a majority of the incoming flow in the original channel cross section. Approximately 40,714 CY of sediment would be used to construct the islands as proposed. Gaps between the islands would allow for navigation into the area of site 13 where feasible.

Options 1–4 are an attempt to maintain the original channel of the Rock River and prevent channel flow from crossing over area 13 and what used to be islands and wetland habitat. In constructing berms for Options 1–4, consideration should also be given to the opposite shoreline of the berm in respect to what impact restricting flow to the main/original channel might have. Some shoreline stabilization may be necessary to protect the shoreline opposite of the proposed berms/islands in Options 1– 4.

Site 10 is labeled Ox-bow as this area was originally an ox-bow on the Rock River. The berms, as proposed on Plate 6, replicate what was once a hard point forcing the river to go around. The intent of re-establishing this point is to return Rock River flow back to its main channel to help keep the main channel scoured. If the original channel depths in this location can be maintained, navigation through this area would be greatly improved without the need for maintenance dredging. It may also enhance deep-water fish habitat. A couple options are available for re-establishing this point. Geotube berms are proposed as shown on Plate 6 and Table 11. However, a jetty-type structure consisting of rock may be feasible as well and would work the same as a Geotube berm. Both structures would perform similarly by standing up to current and returning the flow of the Rock River back to its main channel during normal flows. As with Options 1–4 above, any structure built to re-establish the point that was once there would need to consider the impact to the opposite shoreline. Some shoreline stabilization may be necessary to protect the shoreline opposite of the proposed structure.

Site 1, Dead Creek Mouth, is also an area of concern as Dead Creek contributes the second largest amount of incoming sediment into Lake Sinissippi - 375 tons. Another concern for this area is the loss of wetlands and aquatic plants, because the mouth of Dead Creek has widened and the main channel has become shallower.

One option considered was to create an enhancement area by closing off the area of Dead Creek with a Geotube. The Geotube would allow for shallow water and protection of aquatic plants and could form a sediment trap for incoming sediment from Dead Creek. After reviewing this option further, it was decided that closing off the area where Dead Creek enters the lake to form a sediment trap would not be very effective. Section B-1 discusses the sediment trap concerns in more detail. The current proposed option for Area 1 where Dead Creek enters the lake, is to place a Geotube as shown on Plate 6 to create an enhanced area for wetland and aquatic plants.

B. SEDIMENTATION REDUCTION

Sediment reduction is the long-term key to minimizing the need for costly maintenance dredging. The method to minimize maintenance dredging would require working with Dead Creek and Rock River watershed property owners to implement soil conservation methods in order to reduce the amount of sediments entering the system. The bulk of the sediment that has reached Lake Sinissippi is fine, clay soil which likely has originated from the disturbed areas in the watersheds, including agricultural fields and construction zones. Terracing, buffer strips, detention ponds, and rain gardens are just a few ideas that could be promoted for use in the watershed to decrease surface runoff. This would allow surface water time to infiltrate and slow down surface runoff, reducing velocities which cause erosion to sweep sediment away and into the channel. Implementing these practices in the watershed will reduce sediment entering Lake Sinissippi, improve water conditions, and save dredging/maintenance costs. However, as long as there is water flowing, there will always be a certain amount of sediment being carried in the water column as a result of normal fluvial processes, and thus a continued need for sediment management on the lake. Figure 11 shows one example of how the LSID has implemented plans to reduce sediment entering Lake Sinissippi.

Figure 11. Galvanized steel collar, gravel and drain tile on Lake Drive road culvert that drains into Lake Sinissippi. The culvert collar traps sediment flowing in road ditches, while allowing clear water to pass into the culvert and flow to the lake. LSID worked with the local township to install several sediment retention structures on road culverts in 2006.

1. SEDIMENT TRAP

Sediment traps were considered for both Dead Creek and the Rock River as a way to decrease maintenance costs by trapping sediment in one location, instead of allowing sediment to cover the entire lake. One of the ideas considered utilizing deep holes at the mouth of the Rock River and Dead Creek to create a pool. Upon entering the pool, water would slow down as the channel size increases, which would facilitate sediment dropping out of suspension. To a degree, Dead Creek already has a natural sediment trap as it first enters into Lake Sinissippi. However, a good portion of the sediment being carried in is still suspended in the water as it slowly moves out into the lake.

The 2009 dredging project at Dead Creek created a sediment trap by removing 3,000 CY of sediment from a 125-foot linear section of the stream. This region will function as a settling basin to capture heavier solids carried downstream from the watershed.

Another idea was to consider using a Geotube containment structure to construct a weir in the bay where Dead Creek enters the lake to try and trap or slow down water entering in from the creek. Without testing or modeling this idea, it is the opinion of the Corps that this would have minimal impact on reducing sediment deposition further out in the lake. This could be minimally effective on Dead Creek, but this idea would be infeasible on the Rock River due to the amount of inflow.

After some analysis, the idea of sediment traps for these two tributaries would most likely have minimal impacts due to the fine particle sediment load being carried into the lake. The key to the sediment trap is to have a large enough area to detain inflow long enough so that sediment has a chance to fall out. Table 12 shows particle sizes and the estimated time it takes for those particle sizes to settle out from the water column. Considering the particle size that is coming into the lake and the volume of water coming with it, it would take a large area to hold the water to allow the small particles to fall out. In effect, Lake Sinissippi is the large area sediment trap for these smaller particles. For larger particle sizes, such as fine to coarse sand, the sediment traps for Dead Creek and the Rock River could be effective. In essence, this is already occurring where these two tributaries enter the lake, right at the point of channel widening. This point of channel widening on Dead Creek is located in the vicinity of area 1 on Plate 6

Table 12. Table of Settling times for Various Particles to Settle 70 Centimeters

Class	Mean Dia	Settling Vel	Settling time			
	Cm	cm/s	Seconds	Minutes	Hours	Days
Clay	.0003	0.0008	86,660	1,444	24	1.00
Very Fine Silt	.0006	0.0022	31,197	520	9	0.36
Fine Silt	.0011	0.0109	6,446	107	2	0.07
Medium Silt	.0023	0.0475	1,474	25	0.41	0.02
Coarse Silt	.0045	0.1817	385	6	0.11	n/a
Very Fine Sand	.0088	0.6950	101	2	0.03	n/a
Fine Sand	.0177	2.8118	25	0.41	0.01	n/a
Medium Sand	.0345	10.6826	7	0.11	n/a	n/a
Coarse Sand	.0707	44.8619	2	0.03	n/a	n/a
Very Coarse Sand	.141	178.4340	0.39	0.01	n/a	n/a

2. SHORELINE STABILIZATION

Eroding shorelines and loss of islands have been problems in Lake Sinissippi that also contribute to sedimentation. Plate 12 was constructed with information obtained from LSID showing property ownership, shoreline erosion severity rating, and current protection. Review of the map indicates that a majority of property owners with houses have already protected their shorelines. The majority of the unprotected shorelines are located on remaining islands, northern and western undeveloped lands, and the river bank.

The WDNR has rating criteria to determine what shorelines can be protected from erosion with hard armoring or other types of protection. These criteria are established under Subchapter I Shore Erosion Control Structures, Chapter NR 328 Shore Erosion Control Structures in Navigable Waterways. The types of shoreline erosion protection structures are regulated through a permitting process. The shorelines of Lake Sinissippi rank in the low to moderate erosion energy categories for the type of protection that can be used to reduce erosional loss of shoreline. Low to moderate energy categories indicate that vegetative types of protection can be used. These can include willow plantings, coconut mats, vegetated armoring and, in some cases, traditional riprap.

Table 13. Wisconsin Shoreline Stabilization Categories

	Low	Moderate	High
Biological Controls	GP	GP	GP
Vegetated Armoring	NA	GP	GP
Riprap	NA	IP	GP
Seawall	NA	NA	IP

GP-- General Permit Required
IP -- Individual Permit Required
NA -- Permit Not Available

Plate 12 shows the shoreline of Lake Sinissippi, with the shore erosion energy category designated for each tax parcel as determined by application of the rating criteria of chapter NR 328. All shorelines of the lake are either in the low or moderate erosion energy categories.

One type of shoreline protection that would also achieve the objective of relocating and reusing lake sediment would be to construct breakwaters out of sediment-filled geotextile tubes or other types of inert material permitted under chapter NR 328. This would allow for the reuse and placement of sediment, as well as protecting shorelines by reducing wind fetch. Another advantage to this option is that wetland vegetation and other aquatic macrophytes could be established behind these breakwaters, further protecting the shoreline and establishing habitat for waterfowl, fish, and other species.

Several types of shoreline protection that could be used in Lake Sinissippi are included in Appendix A. Also enclosed in Appendix A are WDNR and NRCS guidelines for shoreline protection design and implementation.

IV. ENVIRONMENTAL ENHANCEMENT

A. AQUATIC PLANT HABITAT ENHANCEMENT

1. BREAKWATER CONTAINMENT AREAS

Riparian wetlands of Lake Sinissippi have undergone varied expansion and contraction during the 165 years of the river impoundment. Documentation of the changes is available through historical aerial photographs and maps. The lake shoreline between the Ox-Bow and the Hustisford Dam show minimal changes; however, river shoreline and associated wetland habitat north of the Ox-Bow have experienced significant loss. Also, wetlands in several small embayments in the lake have contracted due primarily to high water levels and, to a lesser extent, the action of carp.

An earlier aquatic plant survey found that lake vegetation has low species diversity and minimal biomass of rooted aquatics, with primarily floating and emergent plants. Water lily (*Nuphar* spp.) is a major floating plant variety found in the lake, while the dominant emergent wetland plant is cattail (*Typha* spp.). Cattail is tolerant of continuous inundation and seasonal drawdowns, but is generally restricted to areas where the water depth is less than 2 ½ feet, and typically to water depth less than 1 ½ feet.

The LSID successfully completed a test project in 2006 by installing a Geotube geotextile container across the opening to area 6 (Geotube Pilot Site as shown on Plate 6 near Wildcat Road, see Figures 12, 13, 14 and 15). The tube was filled hydraulically with 1,500 CY of sediment from the lake. The 760-foot tube, 30 feet in circumference, was placed and filled so that the final height of the tube was 1 foot above the water surface, creating an offshore breakwater. The backwater area was filled with an additional 1,500 CY of lake bed material to create suitable water depth for aquatic plants, such as white and yellow lily, to be established. At the east end of the tube, a steel screen was inserted between the shoreline and the tube to allow water levels to fluctuate and keep carp out of the backwater area. This project successfully demonstrated that sediment could be relocated from one area of the lake to provide habitat enhancement in another part of the lake; thus achieving three goals of beneficially reusing lake sediment, reducing sediment depth in recreational areas, and re-establishing aquatic plants and wetland habitat. As a result of high water conditions during 2008 flooding, the Geotube was overtopped and carp are once again within the embayment. Future carp eradication may be necessary.

Lake Sinissippi is an eligible waterway to apply for permits to establish offshore breakwaters for the purpose of controlling shore erosion and preserving or restoring aquatic habitat. The project at Wildcat Road was conducted under authority of chapter NR 328, Wisconsin Administrative Code, Standards for Shore Erosion Control in Lakes and Impoundments, Subchapter II Municipal Breakwater Permits.

Figure 12. Geotube® geotextile containment tubes being filled with 1,500 cy of sediment. Note: This is done via hydraulic dredging from lake bottom near Wildcat Road, Lake Sinissippi, May 2006.

Figure 13. "Aerial photograph of Geotube breakwater structure and sediment berm on Lake Sinissippi, showing improved water clarity within contained 24-acre embayment. Installation completed in May 2006. Photograph taken August 2006."

Figure 14. Geotube geotextile containment tubes, 760 feet long. Note: These tubes are functioning as breakwater across opening to 24-acre embayment to stabilize shoreline and existing wetlands, reduce the flow of sediment to lake from creek that empties into the back bay, provide mechanism to reestablish aquatic macrophyte community, improve habitat for waterfowl, and enhance hunting and other recreational activities. Lake Sinissippi at Wildcat Road, May 2006.

Figure 15. "Cattail (Typha sp.) and duckweed (Lemna sp.) on the embayment side of the Geotube breakwater structure, Wildcat Road, Lake Sinissippi. Duckweed is an important food source for waterfowl and turtle, provides shelter for amphibians and is associated with lily, cattail and pickerelweed. A free-floating flowering plant, the daughter plants and seeds of duckweed remain in sediment until appropriate conditions occur for germination and development."

2. WATER LEVEL MANAGEMENT

Water level management is another tool that can be used for promoting growth of aquatic vegetation. Lake drawdowns expose bottom sediment to drying and freezing and allow for germination and growth of vegetation. When the water level is decreased, several lake management procedures can also be conducted: sediment compaction and removal, shoreline stabilization, removal of hazards, and fish management.

Sediment compaction may be aided by freezing and thawing of saturated sediment, which causes some of the water bound to silt particles to separate from the sediment. Further desiccation of sediment may occur during warm weather. The degree of compaction is dependent upon a number of factors, including type and composition of the sediment, depth of drawdown, weather conditions, and location of springs within the lake bed.

Refilling the lake following drawdown will rehydrate the dry sediment. Whether the compacted sediment layer remains intact, or undergoes partial resuspension and expansion, depends on the process of rehydration, mixing of the water from wind action and boating, and the effect of carp on the lake bottom. The drawdown of Lake Sinissippi in 1972-1973 is reported to have had minimal effect on sediment compaction.

In 1969, the Rock River Reclamation Project was initiated by the WDNR with a goal of restoring sport fish populations and waterfowl habitat in the river system. The Hustisford Dam was opened November 1971 to allow for a 4-foot drawdown of the lake. Wet weather conditions during 1972 necessitated an extension of the drawdown through the summer of 1973, with treatment of fish toxicant in August 1973.

Vegetation began to grow on the exposed lake bottom during the early phase of the drawdown in 1972. The extended drawdown period provided conditions for prolific growth of vegetation on exposed lake bed and mudflats. Immediately following the carp eradication and refilling of the lake basin in 1973, suspended sediments quickly settled and extensive growth of aquatic vegetation occurred.

Re-introduction of gamefish and panfish by the WDNR began in fall 1973 following carp eradication and again in spring 1974. Subsequently, winter and summer oxygen depletion events severely impacted the developing sport fishery. The carp population quickly increased soon thereafter.

Three years after the lake was refilled, growth of cattail fringe and other aquatic vegetation made the lake unusable for boating and other recreational activities. Beneficially, however, the waterfowl and mammal populations responded positively to the marsh-like environment; wildlife was abundant with excellent opportunities for hunting and trapping.

The dense vegetative growth continued for about 10 years after the drawdown and carp eradication. The dense growth led to the formation of a property owners' weed harvesting operation in June 1979 to open navigational channels in the lake. In 1983, carp were again abundant throughout the river-lake system, rooted aquatic plant growth became sparse in the lake, and turbid water caused a decrease in water clarity.

As a result of continued sedimentation, water depth of the lake has decreased since the 1972-73 drawdown. A 4-foot drawdown at the present time would expose even more of the lake bottom, rendering most of the littoral zone inaccessible to open water and leading to more extensive plant growth throughout the lake basin. Plate 10, which was provided by Mapping Specialists, shows the areal extent of exposed lake bottom and littoral zone as a consequence of a 4-foot drawdown of the lake. Essentially, all of the riparian lands of the lake community and the Village of Hustisford would be unable to access open water.

A lake drawdown would provide expansion of emergent macrophyte beds. However, if the population of carp remained large, and with a return to normal water level, the macrophyte beds would inevitably recede in several years. To maintain longer-term benefits for wetland restoration, drawdowns would need to be accompanied by carp eradication and likely repeated on a multi-year basis. Periodic or extended drawdowns, however, have the potential of creating a nuisance weed situation that would require cutting or spraying and negatively impacting recreational activities. A shorter winter or summer drawdown would provide an opportunity for dredging of sediment from the exposed lake bed.

Gravity drainage of more than 4 feet is not feasible by just opening the Hustisford Dam. A limestone bedrock ledge near the lake outlet prevents drawdown below 4 feet; drawdown below this depth would require removal of the rock ledge.

3. METHODS FOR SUPPORT OF MACROPHYTE DEVELOPMENT

Aquatic macrophytes are vital components of freshwater ecosystems and must be preserved in moderate abundance for a healthy, productive lake. An earlier inventory of aquatic macrophytes in Lake Sinissippi found three general types of vascular plants including cattail (*Typha* spp.), water shield (*Brasenia schreben*), and water lily (*Nuphar* spp.). Aquatic macrophytes other than cattail were found at only 11 of the 104 sampling locations. Loss of wetland habitat has contributed to a reduction in the number and diversity of waterfowl. Important bird species including American bittern, American black duck, snowy egret, and redhead that once frequented marsh and wetland areas of the lake and river are no longer present.

The distribution of aquatic macrophytes is largely determined by physical factors such as water depth, light penetration, wave action, and sediment texture. Macrophytes are classified into four categories based on their growth habits: (1) Emergent macrophytes such as cattail, bulrush (*Scirpus* spp.), and sedge (*Carex* spp.); (2) Floating-leaved macrophytes such as water lily and some pondweed species (*Potamogeton natans*); (3) Free-floating macrophytes such as duckweed (*Lemna minor*) and coontail (*Ceratophyllum demersum*); and (4) Submergent macrophytes such as watermilfoil (*Myriophyllum* spp.).

Emergent marsh in several embayments has contracted due to high water levels, erosive effects of wave energy from wind and powerboats, and degrading action of carp on rooted aquatic vegetation. Turbid conditions from eutrophication also reduce water clarity, resulting in the disappearance of submerged macrophytes. Loss of macrophytic vegetation caused a shift of the aquatic photosynthetic community to one dominated by planktonic algae. Shoreline vegetative fringe has been reduced to primarily monoculture stands of cattail, with isolated areas of water lily.

Researchers with the Conservation Resource Department of the Parks Division, City of Madison, Wisconsin, and others have had some success in utilizing emergent and floating macrophytes and other natural plantings to establish off-shore and near-shore vegetative barriers to protect and encourage growth of marsh communities (see Figure 16). Experimental techniques used to establish wetland vegetation include placing seeds, tubers, and young plants within enclosures made of brush and tree bundles, wire baskets and hoops, wooden snow fencing, wire U-cages, and sunken mesh fencing, some of which are made of biodegradable materials. Protective planting enclosures help to mitigate herbivory pressure and protect the germinating plants from the destructive action of carp. If conditions are suitable, plant growth will achieve a critical mass and sufficient areal spread to overcome any localized destruction. At that point, the vegetation may spread beyond the containment structures.

The LSID received a grant under the Wisconsin County Conservation Aids Program to evaluate enclosure techniques and test different macrophyte species for establishing off-shore vegetative barriers and near-shore vegetation (see Figure 17). Plants that were used in trials include American lotus, various bulrush species, pickerel weed, yellow and white water lily, redhead grass, and longleaf pond plant. Also, trials were conducted with weighted deep-water duck potato tubers and hand sowing of wild rice seed. These trials were completed in 2009 and results will be evaluated over the next growing season. Additional work is planned to expand upon these experimental techniques in various parts of the lake and river; however, these methods may be more suitable for developing smaller patches of aquatic vegetation within shoreline niche areas. Larger scale restorative efforts will require establishing conditions to encourage germination and development of plants from the native seed bank in lake sediments.

Natural recolonization of macrophytes in the lake will depend upon a number of factors: viability and variety of seeds and other propagules in the lake bottom, lake nutrient levels, degree of turbidity and resuspension of sediment, grazing by herbivorous birds and reptiles, and disturbance by carp. The physical and chemical condition of the lake sediment is another important factor. Phytoplankton dominance in the lake may result in the accumulation of high organic, unconsolidated sediments with low cohesive strength, a factor that would affect the distribution and abundance of macrophytes. The Corps recommends that the LSID evaluate the viability of the native seed bank in lake sediments.

Figure 16: Investigating planted aquatic macrophytes and protective containment structures on the Cherokee Marsh, Yahara River, Madison, WI in 2007.

Figure 17: Protective screened enclosure being installed in the embayment behind the Geotube breakwater. The water depth is about 2 feet. A screen is being attached on the top of the enclosure to prevent access to Canada geese and other herbivorous birds. American lotus seeds and rootstock of water lily species were planted in the sediment within the enclosure. Lake Sinissippi - 2009

B. ISLAND HABITAT ENHANCEMENT

Four of the original twelve main lake islands and river peninsula have been lost due to erosion. Figure 10 shows islands, peninsula, and wetland vegetation that existed in the 1950s in the lower Rock River area and which have been lost. Figure 18 shows recent erosion which isolated the southern tip of the peninsula near the Ox-bow area (labeled as site 10 on Plate 6) due to 2008 flooding. The lake maps in Figures 19, 20, and 21 are from July 1971 and provide historical data of the location and size of lake islands that existed at the time. Three of these islands have since been lost and the remainder is subject to shoreline erosion and continues to lose sediment and vegetation. These locations would be excellent choices for placement of new sediment, creating habitat for many species of birds and mammals and providing for beneficial reuse of lake bed material. The outer perimeter of the island would be constructed of a geotextile containment ring and then sediment could be placed inside the ring until it is topped out of the water. Planting native species of terrestrial plants and trees, as well as aquatic plants, would create a diverse habitat for the species of this area. Plate 6 indicates the potential areas where island enhancement could be utilized. It is estimated that 83,600 CY of sediment could be reused to construct enhanced island habitat for terrestrial ground vegetation and trees.

Figure 18. "High water during flood conditions in June 2008 caused serious erosion problems in the river channel north of Ox-bow. Strong current cut through one of the shoreline peninsulas, isolating the southern tip and dislodging cattail fringe. Eventually, these smaller land masses will be eroded completely."

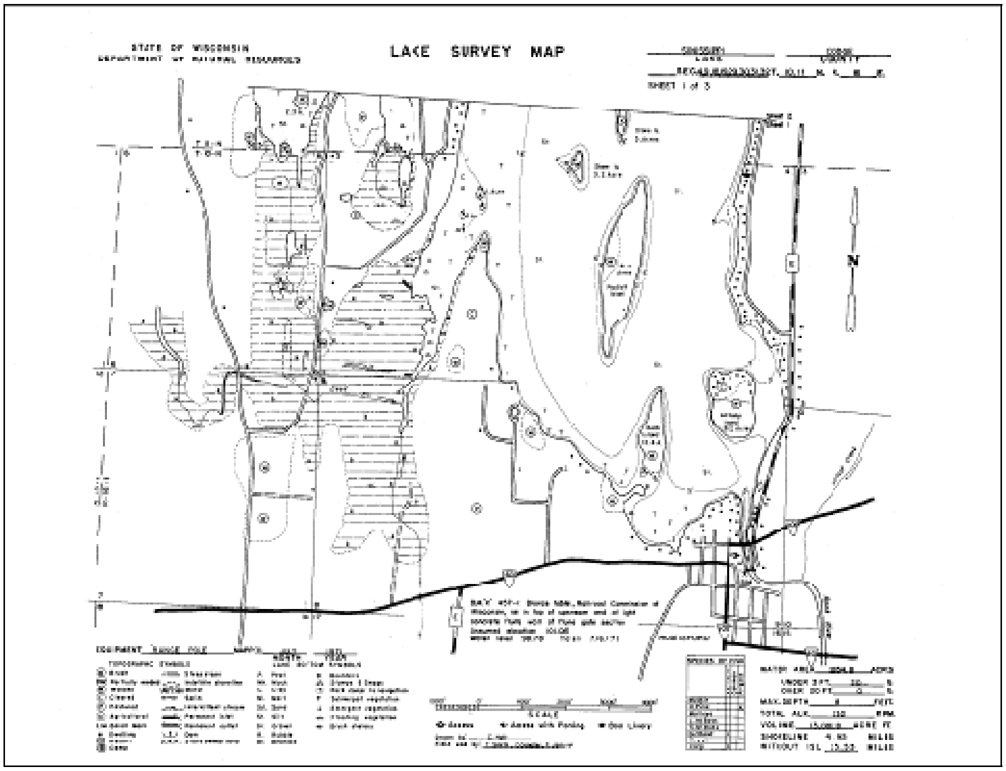


Figure 19. Sinissippi Lake Survey Map, South Reach of Lake Sinissippi, July 1971

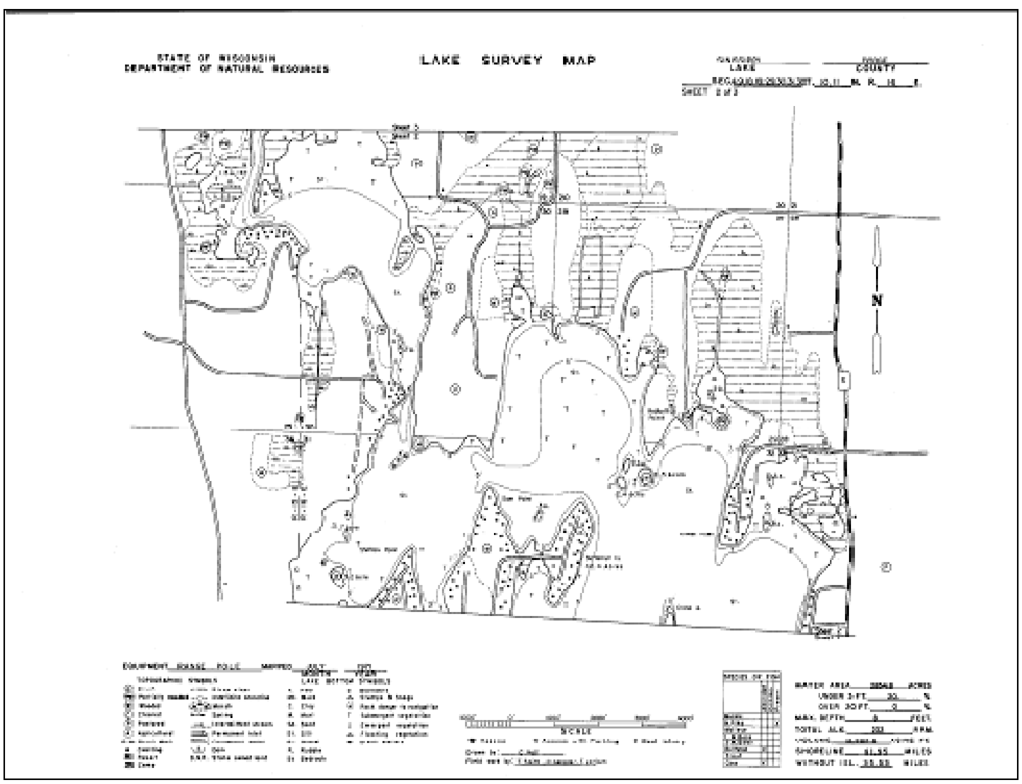


Figure 20. Sinissippi Lake Survey Map, Middle Reach of Lake Sinissippi, July 1971

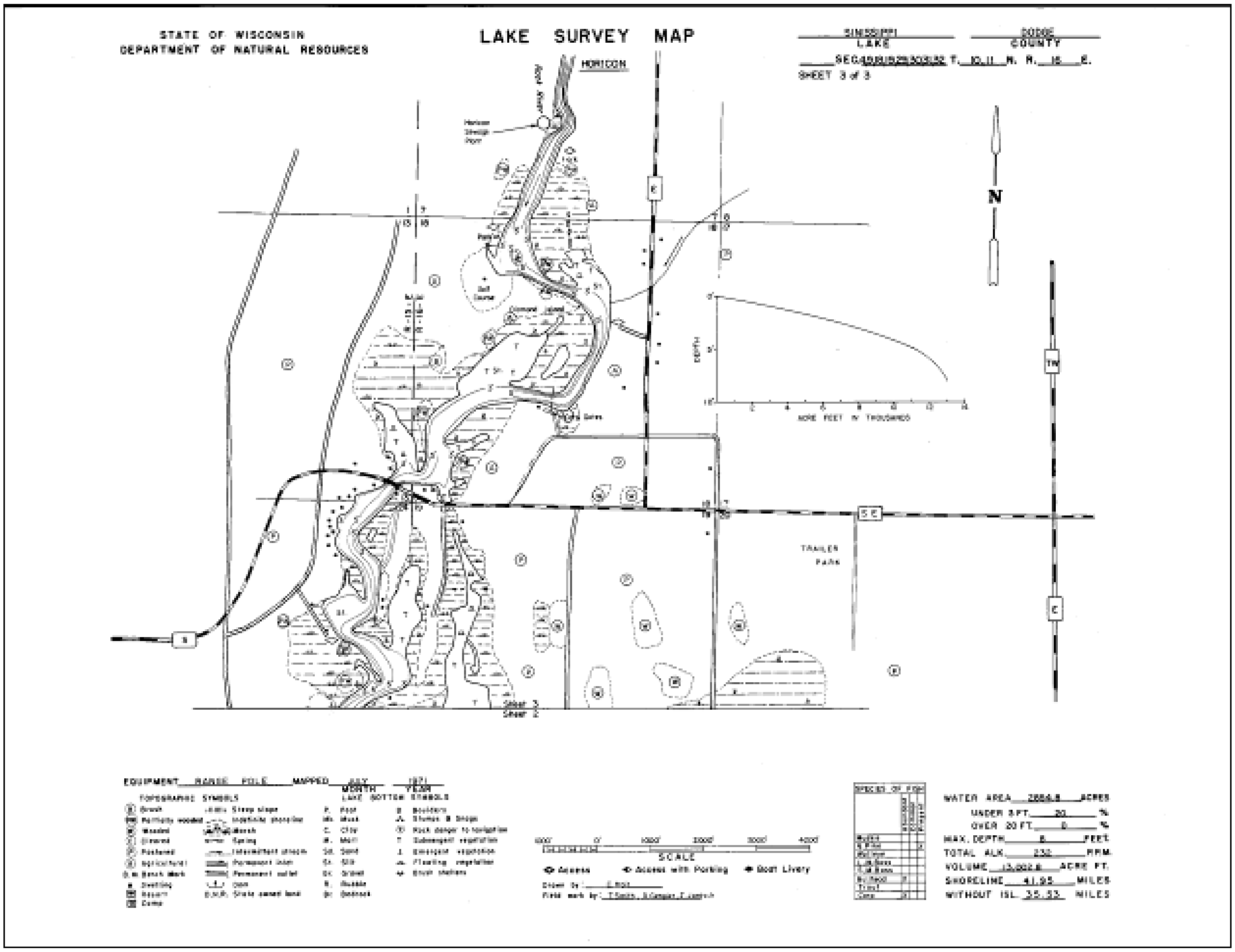


Figure 21. Sinissippi Lake Survey Map, North Reach of Lake Sinissippi, July 1971

Final island elevations would range from 856 to 857 feet, or higher, in some cases. The quantity of dredged sediment for island construction would include additional material to account for changes in topography, shrinkage or settlement. Islands would typically be constructed at a 10:1 slope to mimic the prior natural condition and would allow for vegetation to protect the islands from erosion. Seeding, mulch, and bioengineering methods of erosion control would be required immediately following construction; critical areas would require other shoreline protection methods such as vegetated riprap.

Re-establishing pre-existing islands could have an additional benefit of reducing wind fetch and the potential for sediment resuspension and associated turbidity in the immediate lake area. Resuspension of bottom sediments by wave action can also result in nutrient cycling by transporting sedimentary nutrients back into the water column.

Island construction results in a lake area protected from wave action equivalent in length to 10 times the height of the island. For example, a 6-foot high berm would provide shelter for 60 feet leeward of the wind direction. If trees were allowed to grow on the berm to a height of 30 feet, the sheltered area would be 300 feet. In addition to providing a protected area, an island breaks up waves, resulting in smaller waves on the leeward side of the island. As the fetch length increases, the waves continue to swell until they reach the next obstruction.

When a deepwater wave moves into water with a depth less than one-half of its wavelength (the wave base), it begins to affect the bottom, oscillating water sufficiently to resuspend sediment. The wavelength of a deepwater wave is related to its period by the equation

$$(1) \quad L = gT^2/2\pi$$

where L is the wavelength (meters), g is the gravitational constant ($9.8\ m.s^{-2}$), and T is the wave period (seconds). The period of wind-driven waves is determined by wind velocity, wind fetch, and wind duration. Empirical studies have demonstrated that wind velocity may be assumed to be constant over a period of 1 hour.

Wave period is related to wind velocity and fetch by the following equation

$$(2) \quad gT/2\pi U = 1.20 \tanh [0.077 (gF/U^2)^{0.25}]$$

where U is the wind velocity (meters per second) and F is the effective fetch (meters). Therefore, given wind velocity and fetch on a lake, the resulting wave period can be calculated with equation 2 and the wavelength can be then derived with equation 1. The wave base can then be determined and compared with water depth to the sediment layer at any location to assess the potential for sediment resuspension.

Figure 22 below shows the depth of disturbance of bottom sediment at a given wind speed and wave base (1/2 wavelength). Given the mean depth of Lake Sinissippi as 4.0 ft (1.2 meters) and wind speed of 15 miles per hour, a fetch interval of 200 meters between islands would prevent disturbance of bottom sediment by wind action. In shallow water with depth of 1.5 feet (0.5 meters), the fetch interval would need to be reduced to less than 100 meters. The size of the lake precludes construction of a number of wind barriers; however, placing islands in strategic locations to reduce wind fetch could result in reduction in sediment resuspension.

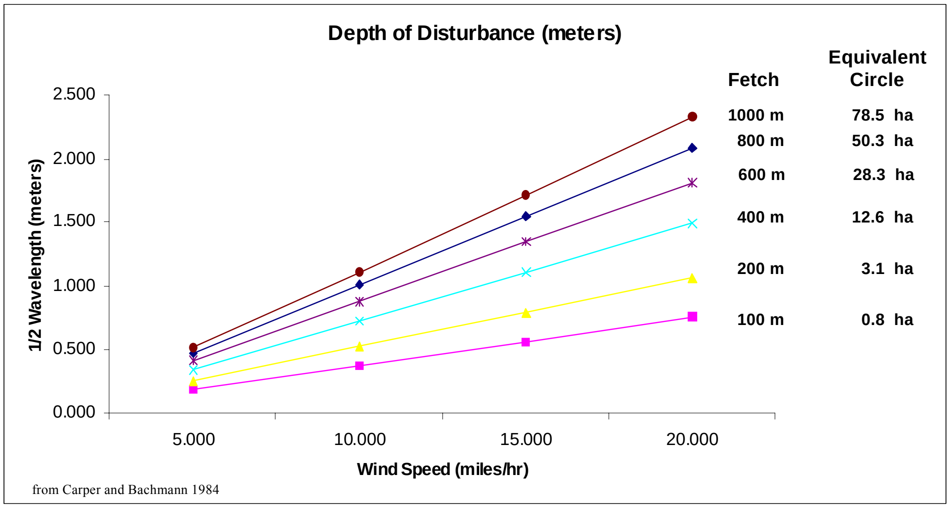


Figure 22. (from Carper and Bachmann 1984)

V. REGULATORY CONSIDERATIONS

Regulatory agency permit requirements for any restoration project on Lake Sinissippi will likely be extensive and consideration will need to be given to various municipal, county, state and Federal regulatory authorities. Additional expenses associated with permit applications may be a significant cost. These expenses can include obtaining sediment chemistry analytical data, engineering consultancy studies, collecting data for a detailed environmental assessment, and evaluating measures to protect water quality and sensitive aquatic habitat.

Additional investigations may also be required to determine suitability of potential upland sediment placement sites, engineering designs for containment berms, and plans for handling return water.

An Environmental Assessment (EA) would be required from WDNR for removing more than 3,000 CY of lake bed material. The EA preparation and evaluation process can be lengthy.

Waterway and Wetland Handbook, Chapter 120 Dredging, provides a detailed review of WDNR legal and administrative purpose, mechanism, history, standards, and process for regulating removal of material from the bed of waterways. The regulatory purpose is to protect public rights against adverse impacts of dredging. Potential in-lake impacts include turbidity, disturbance or destruction of aquatic organisms and habitat, release of contaminated materials, nutrients or other materials entrapped in the sediments, and dissolved oxygen depletion. Regulatory standards also deal with environmental effects to the proposed placement site for the dredged material and the condition and quality of the return water.

Chapter 120 Dredging is available at http://dnr.wi.gov/org/water/fhp/handbook/PDFs/ch120.pdf

Estimates of dredging costs cited in this report will need to be verified with local excavation contractors. Detailed construction plans for specific lake restoration sites and sediment placement sites will be needed so that bidding documents and cost estimates can be prepared. Total costs for restoration will also include any land acquisition, placement site preparation, and site post-restoration. This information will also be needed before permit applications to regulatory agencies are prepared.

VI. BIBLIOGRAPHY

US Army Corps of Engineers Upper Mississippi River System Environmental Management Program Environmental Design Handbook August 2006.
http://www.mvr.usace.army.mil/EMP/designhandbook.htm

US Army Corps of Engineers Dredging Operations Technical Support Program, Beneficial Uses of Sediment, Sediment types http://el.erdc.usace.army.mil/dots/budm/intro.cfm?Topic=Sediment

US Army Corps of Engineers Environmental Lab Wetland Research Program Technical Note HS-RS-4.1 January 1998 Shoreline and Channel Erosion Protection: Overview of Alternatives
http://el.erdc.usace.army.mil/elpubs/pdf/hsrs4-1.pdf

US Army Corps of Engineers Environmental Lab Wetland Research Program Technical Note HS-RS-3.2 January 1998 Geotextile Tube Structures for Wetlands Restoration and Protection
http://el.erdc.usace.army.mil/wrtc/wrp/tnotes/hsrs3-2.pdf

US Army Corps of Engineers Environmental Lab Wetland Research Program Technical Note HS-RS-3.1 January 1998 Wetland Shoreline Protection and Erosion Control: Design Considerations
http://el.erdc.usace.army.mil/wrtc/wrp/tnotes/hsrs3-1.pdf

US Army Corps of Engineers Environmental Lab Wetland Research Program Technical Note WG-RS-3.1 May 1992 Wetlands Engineering: Design Sequence for Wetlands Restoration and Establishment
http://el.erdc.usace.army.mil/wrtc/wrp/tnotes/wgrs3-1.pdf

Landers, J. 2009. Peoria lake dredging project kicks off Illinois River Basin restoration. Civil Engineering. June 2009. pp. 27-29.

Jackson, H.O. and W.C. Starrett. 1959. Turbidity and sedimentation at Lake Chautauqua, Illinois. *Journal of Wildlife Management*. 23/2: 157-168.

Madsen, J.D., P.A. Chambers, W.F. James, E.W. Koch and D.F. Westlake. 2001. The interaction between water movement, sediment dynamics and submersed macrophytes. *Hydrobiologia* 444: 71 - 84.

Lake Sinissippi Improvement District. 2003. *Lake Sinissippi Citizen's Handbook*. Hustisford, WI.

Lake Dredging. 1998. *Lake Notes*. Illinois Environmental Protection Agency, Springfield, IL.

Hey and Associates, Inc. 2006. *Calculations of shoreline erosion potential Lake Sinissippi*. Brookfield, WI. Prepared under Lake Planning Grant from Wisconsin Department of Natural Resources to Lake Sinissippi Association.

Vierbicher Associates, Inc. 2004. *Lake Restoration Study Nagawicka Lake, City of Delafield, Wisconsin*. Reedsburg, WI.

Hey and Associates, Inc., and Lake Sinissippi Improvement District. 2005. *Wetland and Habitat Restoration Planning, Lake Sinissippi, Dodge County*. Prepared under WDNR Lake Planning Grant LPL-866-03 from Wisconsin Department of Natural Resources.

Hey and Associates, Inc. 2002. *Long-Range Implementation Strategy for the Lake Sinissippi Improvement District.* Prepared under WDNR Lake Planning Grant LPL-753-01

US Army Corps of Engineers, Rock Island District. 2007. Summary of wind fetch analysis and evaluation of construction of berms to reduce sediment resuspension at Emiquon East. Preliminary Draft.

US Army Corps of Engineers, Rock Island District. 2007. Emiquon East section 2006 Aquatic ecosystem restoration project. Potential island locations and quantities. Draft.

Carper, G. L. and R. W. Bachmann. 1984. Wind resuspension of sediments in a prairie lake. *Can. J. Fish. Aquat. Sci*. 41: 1763-1767.

Planning Assistance to States, Section 22 Program for The Lake Sinissippi Improvement District *Bulk Sediment and Grain Size Analyses Results* November 2003.

Hefty, R. 2006. Emergent Wetlands Restoration in Cherokee Marsh. PowerPoint presentation of Conservation Resource Department, Parks Division, City of Madison, WI.

Hilt, S., et al. 2006. Restoration of submerged vegetation in shallow eutrophic lakes – A guideline and state of the art in Germany. *Limnologia* 36: 155-171.

APPENDIX A

SHORELINE STABILIZATION METHOD

EROSION CONTROL METHODS

If erosion poses a significant threat to lakeshore property, you will need to select the control method best suited to your needs and a method that will meet state regulations. The most common construction materials used for controlling erosion are vegetation, bioengineering, engineered structures (including stone or riprap), and concrete or sheet piling. Because of the restrictions at Lake Sinissippi, the "Examples of" sections are the most relevant examples for this project.

1. Vegetation

Shoreline vegetation protects property naturally, effectively, and inexpensively. Erosion can result where vegetation has been damaged or removed by construction, herbicide application, or excessive wave action generated by boating. Trees offer excellent erosion control because of their deep roots, which bind the soil, and their leaves, which intercept rain before it impacts and erodes the soil. Lower branches of trees may be trimmed to maintain a view of the lake. Trees and shrubs not only hold soil and nutrients that may otherwise contaminate the lake, but provide an aesthetically pleasing screen to protect the privacy of lakefront property owners. Near-shore water plants can help protect the shoreline against waves and provide excellent fish habitat.

Advantages:

1. Vegetation and natural materials used for protection complement, or become an element of the wetland.
2. Additional habitat can be created. Since the protection is often at the interface between open water and heavily vegetated water or land, it lies within the very productive portion of the wetland. Vegetated banks provide more appealing vistas for humans and more attractive habitat for wildlife, which may otherwise be deterred by unnatural settings.
3. Vegetation is self perpetuating.
4. Vegetation will continue to strengthen and stabilize the bank, assuming that no destabilizing forces overcome the vegetation.
5. Successional or invasional species colonizing a site can add natural variety to the original protection scheme.
6. Vegetation minimizes the potential obstructions to the ingress and egress of organisms to the wetland, as well as the movement of water into and out of the wetland.

Disadvantages:

1. This alternative takes 1-3 years to fully develop.
2. Often requires stabilization measures to protect the vegetation during development.
3. Can be applied only in mild erosional climates.
4. Requires monitoring and maintenance.
5. Minimal guidance is available for designing erosion protection based on wave and current conditions.

Common reasons for failure:

1. No protection during development stage.
2. Improper plant selection, handling, planting technique, or positioning.
3. Poor-quality substrate.
4. No monitoring and maintenance.

Examples of Vegetation

District DNR foresters or biologists and many local nurseries or landscape companies can recommend appropriate plant species for use in and near water. Avoid non-native or invasive species such as reed canary grass, European alder, amur honeysuckle, white mulberry, and purple loosestrife. Trees especially well-adapted to the wet soils along lakeshores include black willow, silver maple, sycamore, green ash, and American elm.

2. Bioengineering

Occasionally, steep bluffs or high wave energy make it difficult to establish or maintain shoreline vegetation. In these circumstances, property owners may need to utilize innovative engineering techniques, such as "bioengineering," to restore shoreline vegetation.

Bioengineering can cost more than either vegetation or riprap alone. However, bioengineering methods can effectively protect highly vulnerable shorelines less expensively than seawalls or retaining walls. Unlike a solid seawall, bioengineering also maintains the valuable shoreline habitat and increases in strength over time as the plants grow. Because of the complexity of these techniques, the assistance of a professional is usually necessary to attain satisfactory results.

Examples of Bioengineering

Trench Packing—This method is used to slow or spread water by placing live plants in a trench perpendicular to the flow. To reduce wave impact, live plants are placed in trenches running parallel to the shoreline. Several trenches may be used with different plants in each, depending on the distance to water. Generally, a wide planting area is needed to dissipate wave energy. In upland areas, trench packing serves to slow water and spread it over the soil surface, reducing its erosion potential. Trench packing also can be used to control shallow seeps, protect wetland construction and renovation, and protect abandoned roads.

Brush Matting—This method protects streambanks by placing a mattress-like layer of branches over them to protect soil and slow water velocity. The mat is composed of interwoven, usually dead branches secured to the soil by live stakes, wire, twine or live branches. Live stakes are often cut from dormant willow. Brush matting helps collect sediment and enables establishment of vegetation on banks. Like brush layering, this method requires large quantities of branches.

Live Cuttings—Live cuttings can be used to secure materials in place and to increase plantings on a slope. Live cuttings can range from 18 inches to 4 feet in length. Longer cuttings are used for live staking of wattles, while shorter cuttings are used for plantings.

Coir Fascines—Coir fascines are wattles made from the fibrous outer husk of coconuts. Coir is denser than water so it won't float and is very slow to decay. Coir fascines are a readily available manufactured product and are popular for streambank and wetland restoration where a natural look is desired (Figure 1). Coir fascines are placed with their tops at the water surface. Live plants can be placed into coir fascines to create a natural look.

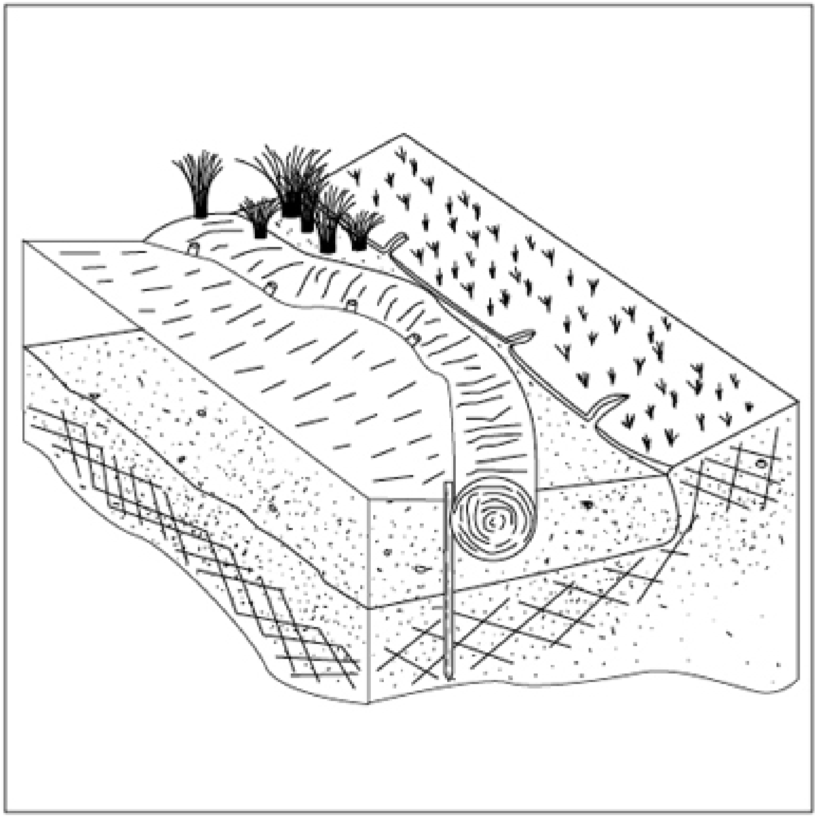


Figure 1. Coir fascines stabilize banks and help establishment of wetland plants. The coconut fiber accumulates sediment and biodegrades as plant roots develop and become a stabilizing system. (From Bestmann-Green Systems)

Prevegetated Mats—Prevegetated mats are live plants grown on a movable mat of organic material. They come in many sizes and materials, and are moved and installed in one piece. They are generally 4-foot by 8-foot in size for easy handling. Mats are grown in nurseries for up to a year or more to provide a good plant stand. Thin mats can be rolled up and shipped without special packing. Thick mats are handled with heavy equipment because of their weight. Prevegetated mats are made of coir or other slowly degradable material and can use many types of plants. Mats usually are used in wetland or lakeshore environments so wetland plants are the most common. Currently, most prevegetated mats are custom ordered 1 to 2 years in advance.

Staking—Staking is used extensively in bioengineering practice. Stakes can be live or dead. Live staking often is done with willows to stabilize soil or to stake other materials in place. Manufactured timber stakes, 2 to 3 feet long, are used to secure wattles and coir fascines. Timber stakes for upland application need to have a bias, or angle, cut making them easier to install. For wetland or streamside applications, stakes need straight parallel sides to prevent heaving from water pressure.

Biodegradable or Temporary Breakwaters—Temporary breakwaters are installed offshore of the shoreland to provide an area quiescent water, usually when new erosion protection designs and shoreland plant installations are becoming established. The breakwater may be of a temporary nature if it is constructed of biodegradable materials, like jute, coir fiber, willow stakes, etc. or if the structure will be removed after a set period of time, like at the end of the growing season.

Combinations—Combinations of the above practices are usually used for most bioengineering designs. For example, a coir fascine can be used with live plantings, brush matting, and trench packing to restore wetlands or stream channels (Figure 2). New combinations of existing methods, and the use of new materials, will provide creative applications of bioengineering techniques.

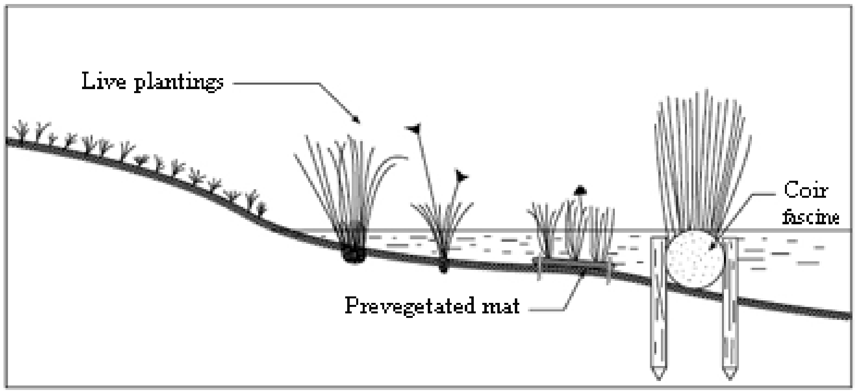


Figure 2. Lakeshore erosion control using a combination design of coir fascine and wetland plantings, prevegetated mat and live plantings. (From A.T. Leiser)

3. Engineered Structures (Including Stone or Riprap)

Large stones placed on top of gravel or a filter blanket will stabilize gradual to moderately-sloped lakeshores by holding soils and dissipating wave action. The size of the stones and width of the stone layer required to effectively protect a shoreline depend on wave height, slope of the shoreline, fetch (extent of open water near the shore), and distance between the high and low water lines. Where underwater beaches reach the shoreline, use of pea gravel (small rounded stones about 1/4 inch diameter) is the only allowable material, because it will provide more stability than sand in eroding or unstable areas.

Use of large stones also provides a rocky, natural-appearing shoreline with some habitat value, particularly if vegetation grows up through it. Variations in depth along the shoreline provide diverse habitat for different species of plants and animals. Fish, turtles, crayfish, and other animals look for food and protect their eggs and young among vegetation and gaps in the rocks.

Seawalls constructed of naturally occurring field stone or quarried limestone riprap will protect a shoreline effectively and inexpensively in most cases. However, improper installation can cause any structure to fail. Inadequate protection along the base or toe of a stone wall can lead to erosion and slumping of the material. To protect against such failure, use large stones placed partially into the lake bottom on the lakeward side of the riprap as a buffer against currents and waves. Large ice sheets may roll over the stones, which can cause some rocks to shift and fall. Spring maintenance of stone seawalls involves placing these rocks in their original position.

Examples of Engineered Structures

Integrated Toe Protection—Biotechnical integrated toe protection designs have toes made of inert materials including rock and armor units. The bank above the ordinary high water mark (OHWM) may incorporate inert materials if necessary into the particular selected design. One crucial aspect of integrated toe protection is the establishment of the hard toe, made of rock and filter cloth. In most instances, this will provide scour protection for the vegetative material located above the toe. When establishing any type of integrated to protection technique, the specifications for individual sites will depend on the amount of wave action and scour activity. Rocks should be lined below the water level at the deepest scour depth over a 3-inch layer of filter cloth and gravel, or a 6-inch layer of gravel only. This will prevent the most destructive wave from reaching the biological shore protection placed above.

Vegetated Riprap—These are techniques that incorporate vegetation into the joints of placed rock into stone riprap. A "Stinger" is a long metal probe mounted on a backhoe, used to create a pilot hole in the joints of riprap for inserting a long and living willow or cottonwood post. Vegetated riprap is an example where normal riprap methods are used; however, plants are inserted between the rock spaces to provide a vegetative covering. This combination of biological and technical shore protection techniques allows excellent waterside erosion protection with natural scenic beauty similar to biological shore protection.

Rock-Log Structures—In protected areas with minimal ice impacts, rock-log structures provide an economical alternative to offshore rock mounds. These structures protect existing shoreline while providing woody structure for fish and loafing areas for wildlife (Figure 3).

Figure 3. Rock-log Structure in Place

Breakwaters—Breakwaters are generally shore-parallel structures that reduce the amount of wave energy that reaches a protected area by dissipating, reflecting, or refracting incoming waves. The reduction of wave action promotes sediment deposition shoreward of the structure. Littoral material is deposited, and sediment is retained in the sheltered area behind the breakwater. Breakwaters may be totally detached from shore or connected at one or both ends.

Advantages:
1. Breakwaters can provide protection in medium to high-wave energy environments.
2. Extensive experience is available for design and construction of rubble mound breakwaters in terms of stability and expected wave transmission.
3. Rubble mound breakwaters that suffer minor damage can still be functional.
4. Breakwaters provide protection with minimum disturbance to the existing shoreline.
5. Segmented, detached breakwaters allow uninterrupted movement of littoral material and aquatic organisms.
6. Aquatic organisms use some breakwaters as habitat.
7. Displaced stone in a rubble mound breakwater can be easily repaired or modified.

Disadvantages:
1. Construction costs can be high due to equipment access requirements for offshore breakwaters.
2. Limited design guidance is available to predict the response of vegetated shorelines behind detached breakwaters.
3. Continuous shore-connected breakwaters may present a barrier to organisms entering and leaving the wetland.
4. Breakwaters may not be aesthetically pleasing to some people

Berms**—**These submerged linear mounds of sediment can be placed offshore from the project site. Berms reduce wave energy incident to the site by causing waves to break as they pass over the structure. Berms should be used in conjunction with other alternatives for bank protection.

Advantages:
1. Add interesting features and variations to local bathymetry.
2. Afford (at least temporarily) some protection against wave energy.
3. Add sediment to the local sediment transport system.
4. Provide a useful means of using otherwise excess sediment from a restoration or creation project.

Disadvantages:
The disadvantages occur when the advantages do not apply. That is, berms are a disadvantage when they do not add useful variations to the local bathymetry but merely cover up existing bathymetry; when they add too much sediment to the sediment transport system; and when they require significant effort to construct but do not survive long enough to provide much protection against incident waves.

4. Concrete or Sheet Piling

Seawalls constructed with an inflexible vertical surface protect shorelines by reflecting wave energy, rather than absorbing it like riprap or vegetation. As a result, such a seawall can worsen wave action on a lake and increase erosion in front of and to the sides of the seawall.

Wave reflection from inflexible seawalls can increase turbidity by stirring the lake bed. Unique and sensitive water plant species, including rushes and other plants necessary for maintaining the fish community, may disappear due to lower water clarity, increased wave action, and scouring of the lake bed.

Near vertical seawalls can permanently degrade shoreline habitat by replacing the naturally sloping shore zone with a vertical face that cannot be used by plants or animals and eliminates gradual and diverse changes in water depth near the shore. Near vertical faces can block access to and from the water for turtles, frogs, and other species that must periodically use underwater areas to feed or reproduce.

Inflexible seawall materials can cost substantially more to install than some other erosion control techniques and may reduce or eliminate vital aquatic habitat. These types of seawalls can require regular maintenance to repair damage from direct wave or ice impact, undercutting by currents or waves, and seepage from the landward side. Due to these constant stresses, seawall strength decreases over time. Common causes of failure include inadequate toe protection, subsidence of backfill soil, build-up of pressure behind the seawall from inadequate drainage or weak anchoring, and direct wave or ice impact exceeding the design specifications of the seawall.

Near vertical seawalls constructed of inflexible materials are best suited to areas with extremely high wave energy, vertical bluffs, at marinas which support intense boat traffic. Negative impacts of a vertical seawall can be lessened by facing the seawall with glacial stone or riprap on the lakeward side.

Examples of Concrete or Sheet Piling

There were no examples relevant to the Lake Sinissippi project.

SOURCES

www.in.gov/dnr/water/files/seawall.pdf
www.ianrpubs.unl.edu/epublic/live/g1307/build/g1307.pdf
www.dnr.state.wi.us/org/water/fhp/waterway/erosioncontrol-biological.html
USACE EMP Environmental Design Handbook
http://el.erdc.usace.army.mil/elpubs/pdf/hsrs4-1.pdf

STREAMBANK AND SHORELINE PROTECTION (Feet) Code 580

Natural Resources Conservation Service Conservation Practice Standard

I. Definition
Treatment(s) used to stabilize and protect eroding banks of streams or constructed channels, and shorelines of lakes, reservoirs, or estuaries.
II. Purposes
This standard may be applied as part of a conservation management system to support one or more of the following concerns.

- Limiting the loss of land and its potential impacts to utilities, roads, buildings, other facilities or cultural resources adjacent to streambanks or lake shorelines;
- Maintaining or restoring channel dimensions (width, depth), meander (sinuosity and meander geometry) and profile (slope, pools, riffles) allowing the channel to transport sediment and runoff without aggrading or degrading;
- Reducing sediment loads that cause degradation of habitat and water quality; and
- Improving or protecting recreation, fish and wildlife habitat, native biodiversity, and natural scenic beauty.

III. Conditions Where Practice Applies

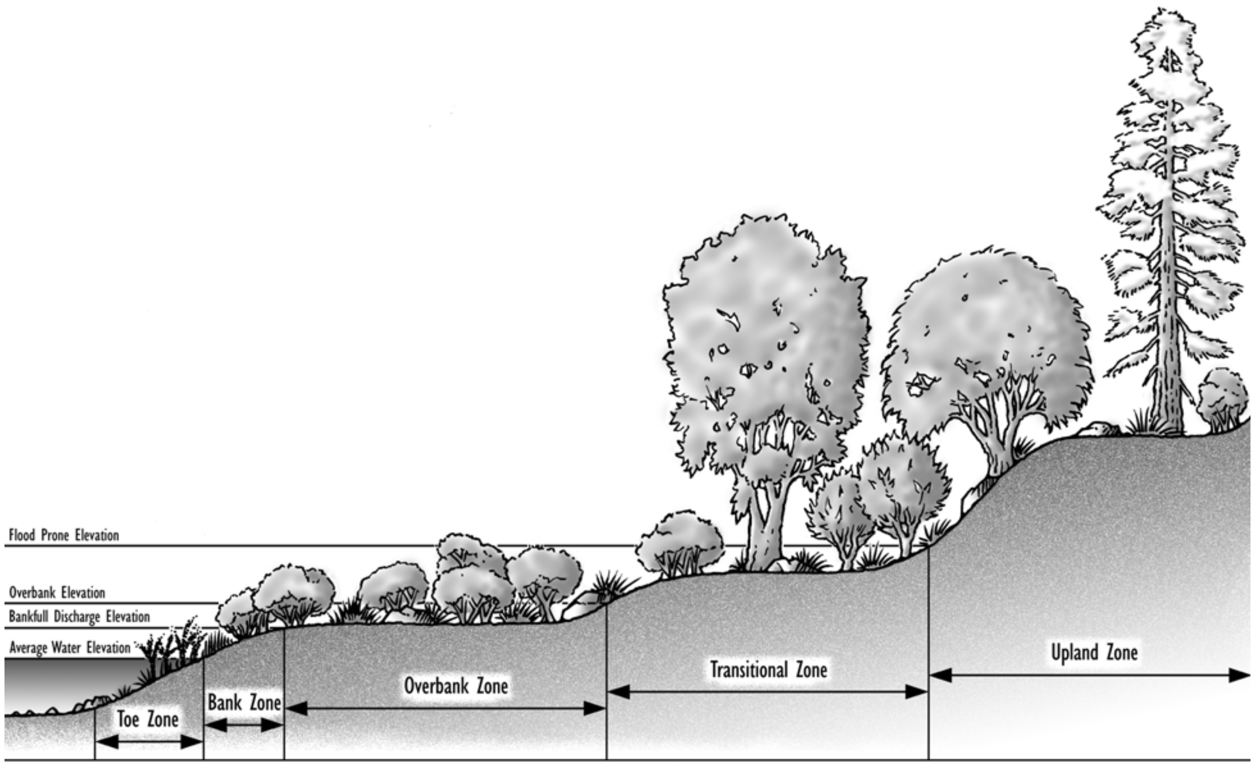
This practice applies to the toe and bank zones of streambanks of natural or constructed channels and shorelines of lakes, reservoirs, or estuaries where they are susceptible to erosion (see Figure 1). This standard applies to controlling erosion using *structural treatments*[1] often in combination with re-vegetation, *soil bioengineering*, or upland erosion control practices (see NRCS National Engineering Handbook (NEH), Part 650, Engineering Field Handbook (EFH), Chapter 16, Companion Document 580-1).
This standard does not apply to erosion problems on the open coastal shorelines of the Great Lakes or similar areas of complexity not normally within the scope of the NRCS authority or expertise.

IV. Federal, State, and Local Laws

Users of this standard should be aware of potentially applicable Federal, state, and local laws, rules, regulations, or permit requirements governing streambank and shoreline protection. This standard does not contain the text of Federal, state, or local laws.
V. Criteria – Establishes the minimum allowable limits for design parameters, acceptable installation processes, or performance requirements.
A management and site assessment of unstable streambank and shoreline sites shall be made in sufficient detail to identify the causes contributing to the instability (e.g., livestock access, watershed alterations or sediment production, water level fluctuations, boat-generated waves, etc.).
Note: An interdisciplinary team may be needed to deal with complex streambank or shoreline projects.
A. Management Assessment, Streambanks and Shorelines – A management assessment of the site shall be conducted and incorporated into the design. The assessment shall be performed with the landowner to determine the purpose of the protection, available resources, and the existing and desired land uses and conditions. The management assessment shall include the following:

1. Land use and management (e.g., cropland, pasture, residential, recreation, fish and wildlife habitat).
2. Vegetation management – Desired conditions of aquatic, *littoral* (lakes), bank, and upland zones, and *access corridor*.
3. Access and use.
4. Watercraft use, restrictions, and potential impacts.
5. Willingness of landowner to carry out required maintenance.
6. Runoff and stormwater management.
7. Landowners desired condition and plans for site.

Figure 1: Location of Hydrologic Zones Along a Streambank or Shoreline



Note: For the purposes of this standard the terms bankfull elevation and OHWM are deemed equivalent.

B. Streambank Site Assessment – A site assessment shall be conducted and incorporated into the design. The assessment shall be performed to determine the physical, cultural, and historical site characteristics that will influence the construction, maintenance, and environmental integrity of the protection.

1. For all projects, the site assessment shall include:

   a. Stream bed stability – Determination whether the stream bed is aggrading, degrading, or stable.

   b. Hydrology and hydraulics, water level fluctuations, *bankfull elevation*, nearby hydraulic structures (e.g., dams, bridges, culverts, storm sewer outfalls).

   c. Bank and bed composition – Soil type, composition, Unified Soil Classification System (USCS) profile log, streambed material.

   d. Identification of the size and location of areas or habitats requiring avoidance (e.g., wetlands, riparian and upland areas, in-stream habitat).

   e. Drainage paths, flow patterns, runoff controls, roof gutters, impervious areas.

   f. Length of treatment area and accessibility for equipment.

   g. Site sketch or checklist illustrating items V.B.1.a through f.

2. For single sites over 300 feet in length, or multiple sites in a ¼ mile reach totaling over 500 feet, assess items V.B.1.a through f, and the following items:
   a. Determination whether the causes of instability are local (e.g., poor soils, seepage, alignment, obstructions

deflecting flows into bank, etc.) or watershed related (e.g., aggradation due to increased sediment, increased runoff due to urban development, degradation due to channel modifications, etc.).

b. Stream classification (Rosgen, 1994) (slope, sinuosity, entrenchment, width, depth, bed material) and stage of evolution (Schumm, 1984).

c. Waterway designation: Areas of special natural resource interest, outstanding and exceptional resource waters (ORW, ERW), trout stream classification, type (cold or warm water, fish habitat) and characteristics.

d. Stability of bank, stream lateral recession rates, bank height, bank angle, percent of bank protected by vegetation, rooting depth and density, presence of existing erosion control practices.

e. Tiers of vegetation – Aquatic, bank, and upland. Presence of invasive species.

f. Number and orientation of existing or proposed decks, steps, piers, access points to water body, utilities, etc.

g. Documentation of cultural and historical resources.

h. Aquatic/terrestrial habitat and movement corridors for wildlife in a watershed context.

i. Site sketch, photographic documentation or checklist illustrating items V.B.2.a through h (including items V.B.1.a through f).

C. Shoreline Site Assessment – A site assessment shall be conducted and incorporated into the design. The assessment shall be performed to determine the physical, cultural, and historical site characteristics that will influence the construction, maintenance, and environmental integrity of the protection. The site assessment shall include:

1. Determine if causes of instability are local (e.g., lake or overland actions, ice, seepage, sediment accumulation, littoral drift, etc.) or watershed related (e.g., water level control structure, recreation, etc.).

2. Waterway designation (area of special natural resource interest, ORW, ERW) and size and type of water body (seepage lake, groundwater drainage lake, drainage lake, impoundment).

3. Water level fluctuation, *ordinary high water mark (OHWM)*, water depth at 20 feet and 100 feet from shore.

4. Shore orientation and geometry.

5. Bank recession rate.

6. Average fetch – Measured by the average of a central radial line, perpendicular to the shoreline, and two radials measured at 45 degree angles from the central radial.

7. Drainage paths, flow patterns, runoff controls, roof gutters, impervious areas.

8. Bank and bed composition and stability – Soil type, composition, Unified Soil Classification System (USCS) profile log, bank height, bank angle, percent of bank protected by vegetation, rooting depth and density, presence of existing erosion control practices.

9. Tiers of vegetation – Aquatic, littoral, bank, and upland. Presence of invasive species.

10. Identification of the size and location of areas or habitats requiring avoidance (e.g., wetlands, riparian and upland areas, near shore habitat).

11. Aquatic/terrestrial habitat and movement corridors for wildlife in a watershed context.

12. Length of treatment area and accessibility for equipment.

13. Location and size of access corridor.

14. Number and orientation of existing or proposed decks, steps, piers, access points to water body, utilities, etc.

15. Documentation of cultural and historical resources.
16. Site sketch illustrating items V.C.1 through V.C.15.

D. General Design Criteria For Streambanks and Shorelines – Several general criteria apply to this practice. They are as follows:
1. Because each reach of a channel, lake, or estuary is unique, measures for streambank and shoreline protection must be installed according to a plan and adapted to the specific site. Recommended design procedures are located in the EFH Chapters 3, 16, and 18.
2. Protective measures are to be consistent with management objectives and compatible with other improvements being planned or being carried out.
3. Protective measures shall be compatible with the bank or shoreline materials, water chemistry, channel or lake hydraulics, and slope characteristics both above and below the water line.
4. Protective measures shall be designed to avoid or minimize the potential for increased erosion to an adjacent reach of shoreline or streambank.
5. The impacts of boat-generated waves shall be accounted for in the design.
6. Minimum clearing shall be performed to accomplish the project. Existing vegetation shall be preserved as much as possible.
7. Protection measures shall start and end at a stabilized or controlled point.
8. Control of surface runoff and internal drainage shall be addressed in the design and installation of all protection measures.
9. All disturbed areas shall be protected from erosion during and after construction by implementing a site erosion control plan.
10. Excavated material shall not be placed in wetlands, water bodies, or other areas or habitats requiring avoidance, and shall be stabilized to prevent erosion.
11. Where livestock watering facilities are provided, design shall be as described for channel crossings in NRCS Wisconsin Field Office Technical Guide (FOTG), Section IV, Standard 560, Access Road.
12. Solid waste materials, such as construction debris, or tires, shall not be used for protection.
13. Vegetative Treatments
Note: See EFH, Chapter 16, pages 10 and 73 for further guidance.

a. Vegetation shall be selected that is best suited for the site conditions and intended purpose. The vegetation may need to tolerate frequent or long durations of inundation.

b. Vegetation establishment shall be done in accordance with the conservation practice standards contained in the NRCS FOTG, Section IV.

c. Existing stable *bank zones* may remain unshaped and treated with vegetation only.

d. Bank zones to be treated only with vegetation that require shaping to be stable shall be sloped to a 2 horizontal to 1 vertical (2:1) side slope or flatter. Steeper slopes may be installed if a slope stability analysis can demonstrate adequate stability.

e. Structural treatments shall be provided in the *toe zone*.

14. Soil Bioengineering Treatments
Note: See EFH, Chapter 16, pages 33-61, 64-72, and 80 for further guidance

a. Treatments shall follow the applicable "application and effectiveness" criteria found in EFH, Chapter 16, or other widely accepted references.

b. Structural treatments shall be provided in the toe zone area.

c. Installation shall be in accordance with NRCS specifications, or other widely accepted references.

15. Structural Treatments
Note: See EFH, Chapter 16, pages 33-61, 64-72, and 80 for further guidance.

a. Structural treatments shall be selected and designed that are best suited for the site conditions and intended purpose.

b. Riprap revetments or other sloped structural measure stabilization practices shall be sloped to a 1.5:1 vertical side slope or flatter.

c. Riprap revetments D_{50} shall be sized using EFH, Chapter 16, methods (e.g., wave heights for shore protection or velocities for stream bank protection).

d. Other structural treatments shall be designed to be stable for all anticipated load conditions. They shall, at a minimum, be designed and installed according to manufacturer's specification data.

e. Bulkheads shall be designed to be stable for all anticipated load conditions.

16. Other proposed methods or materials shall meet or exceed the level of protection expected from conventional practices. They shall, at a minimum, be designed and installed according to manufacturer's specification data.

E. Specific Streambank Design Criteria – Several streambank criteria apply to this standard. They are as follows:

1. The channel grade must be controlled, either by natural or artificial means, before any permanent type of bank protection can be determined feasible.

2. Treatment measures shall be constructed to at least the:

a. Minimum depth of the *anticipated bottom scour*.

b. Highest elevation of the following

i One foot above base flow conditions.

ii To the height of seep lines in the bank, if not controlled in some other fashion.

iii Bankfull elevation.

3. Channel clearing to remove stumps, fallen trees, debris, and sediment bars shall only be performed when they are causing or could cause unacceptable bank erosion, flow restriction, or damage to structures. Habitat forming elements that provide cover, food, pools, and water turbulence shall be retained or replaced to the extent possible.

4. In-stream structural treatments installed to redirect flow away from eroding banks may be used. Measures shall be designed using EFH, Chapter 16, methods.

5. Significant alterations to channel alignment or channel geometry shall be made only after an evaluation using current fluvial geomorphologic techniques. Effects on the land use, interdependent water disposal systems, hydraulic characteristics, wetlands, and existing structures shall be investigated.

6. Treatment measures shall be stable for the minimum design flow based on what the treatment is protecting unless out-of-bank flow occurs at a lower stage. Minimum design flows shall be calculated using USGS Flood-Frequency Characteristics of Wisconsin Streams (formerly known as the Conger method), or NRCS applicable hydrology model (EFH, Chapter 2, TR-55, or TR-20). Minimum design flow return periods are:

• 10 year – for cropland, woodland, pastureland, or other lands.

• 25 year – for uninhabited structures, farm buildings, limited access roads and their appurtenances, parks, and other improved properties.

• 100 year – for residences, businesses, state and local highways and their appurtenances, or other structures which if imperiled would threaten the life and safety of people.

7. Design criteria for livestock or equipment channel crossings shall be in accordance with NRCS FOTG, Section IV, Standard 560, Access Road.
8. Fish habitat improvement or protection incorporated into streambank design shall be in accordance with NRCS FOTG, Section IV, Standard 395, Stream Habitat Improvement and Management. See EFH, Chapter 16, for further information.
9. The design elevations of treatment measures shall be referenced to the bankfull elevation.
F. Specific Shoreline Design Criteria – Shoreline criteria are as follows:
1. Shoreline treatment measures shall be keyed as necessary to prevent anticipated bottom scour.
2. Treatment measures shall be provided to at least the highest elevation of the following:

a. OHWM plus the design storm wave height.

b. To the height of seep lines in the bank if not controlled in some other fashion.

c. The height of boat generated waves.

3. Design elevations of treatment measures shall be referenced to the OHWM.
4. Temporary wave protection may be installed for the purpose of providing an area of quiescent water for the establishment of vegetative treatments. Maintain the temporary wave break until vegetation is well established, at which time the wave protection shall be removed.

VI. Considerations

Additional recommendations relating to design that may enhance the use of, or avoid problems with, this practice but are not required to ensure its basic conservation functions are as follows.
A. When protecting improvements such as utilities, roads, buildings, or other facilities, consideration should be given to items such as cost of stabilization compared to the value of the structure, the possibility of relocating the structure, the remaining service life of the structure, and the effect of the stabilization on the future management system of the landowner.
B. Consideration should be given to maintaining and increasing native vegetation.
C. When planning streambank and shoreline protection, consider the following water quality effects:

- vegetation filtering the movement of sediment, absorbed sediment, and dissolved substances;
- erosion and movement of sediment and sediment-attached substances carried by runoff and stream flow;
- visual quality of on-site and downstream water resources;
- construction and vegetation establishment;
- changes in water temperatures; and
- wetlands and water-related wildlife habitats for short and long-term periods.

D. Artificial obstructions, such as fences or barriers, may be used to protect vegetation needed for streambank protection or to protect critical areas from damage by trail or vehicular traffic. Where needed, construct a permanent fence capable of excluding livestock from the streambanks. Refer to NRCS FOTG, Section IV, Standard 382, Fence. Floodgates may be used at channel crossings, property fence lines, and at other fence lines. Refer to EFH, Chapter 16, for an example of a floodgate.
E. Observe adjacent stabilization treatment measures and comparable sections of shoreline when available.
F. Stabilization practices using structural treatment measures are effective in the following situations:

- sharp bends, at bridges where velocities are increased,
- along the opposite bank where another stream junctions,
- on large streams, and

• on shorelines with slumping due to seepage.

G. Check for existing lake, stream, or watershed management plans and aim to make the protection project consistent with management objectives.

VII. Plans and Specifications

Plans and specifications for streambank and shoreline protection shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

VIII. Operation and Maintenance

An Operation and Maintenance Plan shall be developed with the landowner or operator that is consistent with the purposes of this practice, intended life of the components, and criteria for design.

IX. References

B. Shaw, C. Mechenich, and L. Klessig. Understanding Lake Data, UWEX G3582 (SR-02/2002-1M-525).
Federal Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US government). Stream Corridor Restoration Principles, Progress and Practices, GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN3/PT.653. ISBN-0-934213-59-3. 2001.
http://www.nrcs.usda.gov/technical/stream_restoration/newgra.html.
Rosgen, David L., 1994. A Classification of Natural Rivers. Catena vol. 22. Elsevier Press. p. 169-199.
Schumm, S.A., Harvey, M.D. and Watson, C.C. 1984. Incised Channels – Morphology, Dynamics and Control. Water Resources Publications. 200 pp.
USDA, NRCS, Wisconsin Field Office Technical Guide (FOTG), Section IV, Practice Standards and Specifications.
USDA, NRCS, National Engineering Handbook, Part 650, Engineering Field Handbook, and Wisconsin supplements.
USDA, NRCS, National Design, Construction, and Soil Mechanics Center. Streambank Soil Bioengineering Field Guide for Low Precipitation Areas.
USDA, NRCS, National Water and Climate Center. Stream Visual Protocol, Technical Note 99-1.
USDA, NRCS, Wisconsin Biology Technical Note WI-1, Shoreland Habitat.
Wisconsin Department of Natural Resources (WDNR). Designated Waters Search Link: http://dnr.wi.gov/org/water/fhp/waterway/waterslist.shtml.
WDNR. Wisconsin Lakes Book, WDNR pub –FH-800. 2001. (A list of Wisconsin's lakes and information): http://www.dnr.state.wi.us/org/water/fhp/lakes/list/ #lakebook.
WDNR, Lake Types - Understanding Lake Data: http://www.dnr.state.wi.us/org/water/fhp/lakes/under/ laketype.htm.
WDNR, Trout Stream Classifications. Information and maps are located on the WDNR website: http://dnr.wi.gov/org/water/fhp/fish/species/trout/ streamclassification.shtml.
WDNR, Water Quality Standards Section link to ORW/ERW: http://dnr.wi.gov/org/water/wm/wqs/.
Wisconsin Department of Transportation. Erosion Control Product Acceptability List: http://www.dot.wisconsin.gov/business/engrserv/pal.htm.
USDA, NRCS, Technical Release 55, Urban Hydrology for Small Watersheds.
USDA, NRCS, Technical Release 20, Computer Program for Project Formulation Hydrology.

X. Definitions

Access Corridor (V.A.2.) – Typically a low growing vegetated strip of land that provides pedestrian access and a view of the waterfront.
Anticipated Bottom Scour (V.E.2.a.) – The depth necessary to maintain a stable foundation for the life of the practice as determined by accepted methodologies.
Bankfull Elevation (V.B.1.b.) – In Wisconsin, the bankfull elevation of channels is roughly the water elevation during the 1.2-year discharge. In many channels, this is the point where water begins to flow out onto its floodplain. Note: Since floodplains may be small or inconspicuous in some stream types where floodplains are naturally indistinct or presently being developed, it is important to verify correct identification of the bankfull surface by checking it against the 1.2-year discharge. This can be done using Manning's equation, USGS Flood-Frequency Characteristics of Wisconsin Streams (formerly known as the Conger method), TR20 or TR55, or from gauge data.
Bank Zone (V.D.13.c.) – The area above the toe zone located between the average water level and the bankfull elevation or OHWM. Vegetation may be herbaceous or woody, and is characterized by flexible stems and rhizomatous root systems.
D_{50} *(V.D.15.c.)* – The size of material of which 50 percent of the material sample is smaller by weight.
Littoral (V.A.2.) – The near-shore shallow-water zone of a lake where aquatic plants grow.

Ordinary High-Water Mark (OHWM) (V.C.3.) – Ordinary high-water mark is the point on the shore up to which the presence and action of the water is so continuous as to leave a distinct mark by one of the following: erosion, destruction of terrestrial vegetation, or other easily recognized characteristics.
Soil Bioengineering (III.) – A system of living plant materials with a specified configuration installed as the primary means of soils stabilization.
Toe Zone (V.D.13.e.) – The portion of the bank that is between the average water level and the bottom of the lakebed or channel, at the toe of the bank.
Structural Treatments (III.) – A system of non-living materials with a specific configuration installed as a means of (bank or shore) stabilization including, but not limited to, riprap, tree revetments, log/rootwad/ boulder, dormant post, jacks, coir logs, bulkheads, and stream barbs.

 1 Words in the standard that are shown in italics are described in X. Definitions. The words are italicized the first time they are used in the text.

APPENDIX B

SEDIMENT TRAP CONSIDERATIONS

This Section reviews 5 questions that were raised by the PDT and Sponsor and includes the responses to each; which were made by George Staley, US Army Corps of Engineers Rock Island District Hydraulics Section.

Question 1. Advise recommendations on how to best address the Lower Rock River channel with re-channelizing and incorporating wetland restoration to the side of the channel, example area 13. Propose Geotubes as this would serve two purposes - dredging channel and forming a barrier to protect wetlands on one side and forming/returning flow into the main channel on the other side. Thoughts about this? Any hydraulic impacts?
Question 2. What about using wing dams or dikes to protect shorelines in the Rock River Channel?

Using Geotubes to protect area 13 (Response to Items 1 and 2 George Staley 09-6-25)
Each state has its own rules about construction within a waterway. I do not know which rules the state apply. Is the area 13 considered part of the Rock River or part of Lake Sinissippi? If the plan is to confine the river, the rules for the rive,r rather than the lake, may apply.

The figures included in this section show area 13 prior to 1968 (Figure 1) and in 1999 (Figure 2). The curvilinear shoreline forming the left descending bank of the river as the channel curves around Lehman's Point is clearly evident in the earlier photograph. The later photograph shows the loss of the peninsula and the existing narrow island remnant.

Two options might be considered: a smaller plan to form a berm at the opening of the embayment to the northeast of Lehman's Point (Option 1 on Figure 2), and a larger plan to re-establish part of the main river channel at the peninsula (Option 2 on Figure 2).

I would be tempted to start with the smaller plan. The smaller plan would be easier to get state approval since it would not encroach anyway near the river. However, you may consider that this duplicates the test case you made with a Geotube several years ago. A less expensive test case could be to start at the uppermost peninsula of the "new" larger area 13 and go southwest 500 feet (ending at what used to be an island if it still exists). This would be beneficial to you in that it would demonstrate the concept with a minimum of material and would be completed within a short period of time. It would allow you to monitor how the Geotube structure behaves under conditions of flood, river current, ice, and wind. Once this portion is complete and operational it could be used to justify obtaining permission for continuing with the new area 13 alignment.

I have talked with several people within my work group about my idea of wing dams. Two engineers have rightly pointed out that wing dams are used in areas of high velocity. In the case of Lake Sinissippi, there is no high velocity. The idea of placing the Geotubes parallel rather than perpendicular to the direction of flow has more support in my work group. Also, work to reform the river channel must also consider any hydraulic effect of flow changes on the existing shoreline. Some shoreline stabilization may be necessary to mitigate any increase in erosive effects of flow on the opposite shore.

The state will want proof that you are not encroaching into the river and raising water levels upstream. This might involve basic hydraulic analyses of before and after conditions or by maintaining the river width through the test area at the maximum width measured upstream and downstream of the proposed site (this is a river width of about 500 feet). Some of your hydraulic concerns for designing the Geotube barrier would be the fluctuation of water surface elevation in the vicinity of area 13 during floods. You should also have an idea about the height of waves generated by the wind. This can be determined by equation. Wave height is estimated by knowing the design wind speed, measuring the fetch length, and knowing the water depth. Usually several possible paths are examined. The longest fetch appears to be for wind blowing from the east to the west.

Figure 1. 1968 aerial photo of area 13

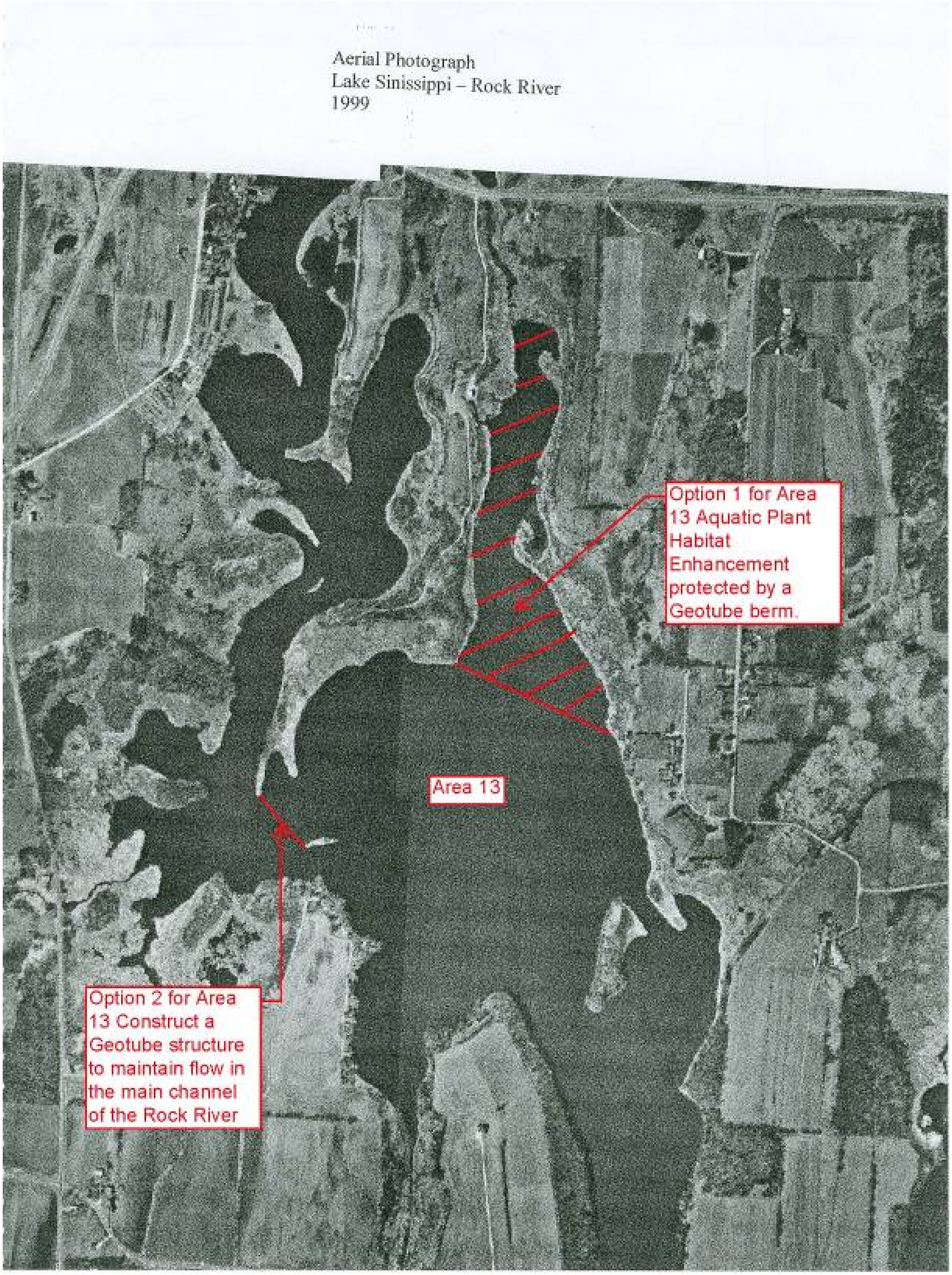


Figure 2. 1999 Aerial photo of area 13

Websites of interest

"A permit is required for the placement of any structure in a waterway. Specific application forms and information are available for certain structures, including boat ramps, boat shelters, bridges, buoys, culverts, dry hydrants, fish cribs, piers, pea gravel blankets, pilings, seawalls, and shore protection structures. For all other projects where a specific application form is not available separately, a miscellaneous structure permit is required. Placement of fill on the bed of a waterway is generally prohibited. This applies to anyone who wants to place a structure or material into a waterway."

DNR issues the permits in Wisconsin
http://www.dnr.state.wi.us/

Waterways permits
http://www.dnr.state.wi.us/org/water/fhp/waterway/

Question 3. Advice or recommendations on how to best address Dead Creek channel with re-channelizing and incorporating wetland restoration to the side of the channel, example area B. Or should this area be dredged and formed into a sediment trap? Sediment is being dredged on Dead Creek upstream to prevent it from reaching the lake.
Question 4. Should a geotube be installed in back water area around the mouth of Dead Creek or not (Area B)? How to keep sediment flowing from Dead Creek to Butternut Island? The backwater area, area B, is also lost wetland area that has been transformed to open water - thus the Geotube idea to recreate a wetland area and have another sediment placement opportunity (two purpose plan again). Good idea?
Question 5. Any ideas on how to create a sediment trap at Dead Creek or the Lower Rock River?

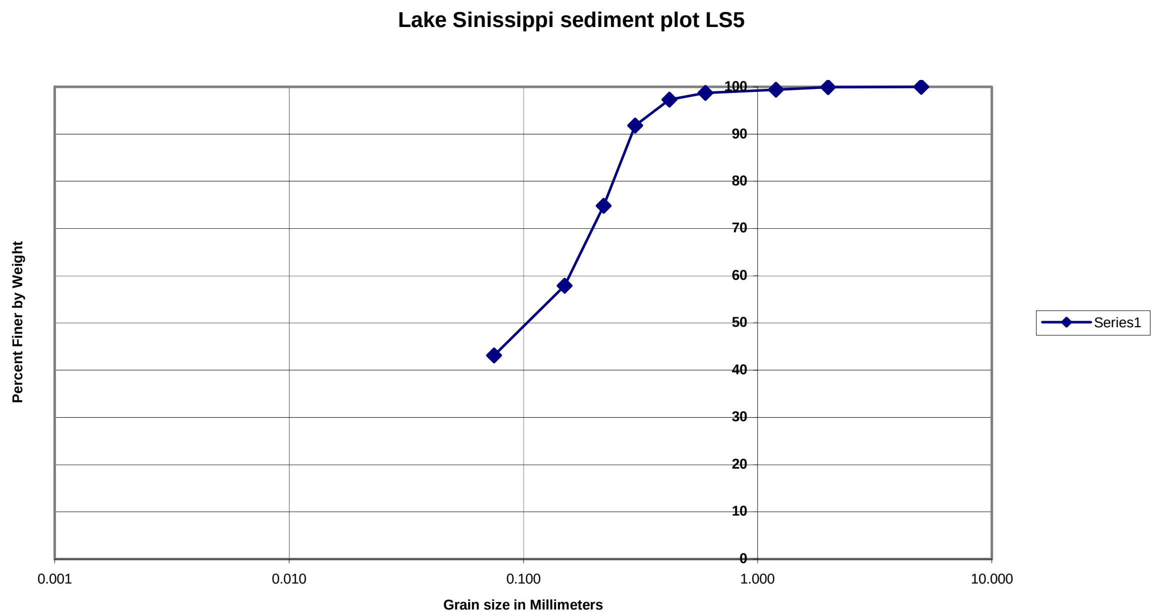
Building a sediment trap downstream of the mouth of Dead Creek? (Response to Items 3, 4 and 5 George Staley 09-6-25)

Dead Creek enters Lake Sinissippi with the bank of the lake on the left descending bank of the creek (looking downstream) and a peninsula on the right descending bank of the creek. The width of the creek expands greatly while the depth of the water remains constant (since the depth of the lake also determines the depth of the creek). Because the cross-sectional area of the creek increases, the velocity will reduce as the water flows toward the lake forming a natural sediment trap. I think adding a tube to capture more sediment would have a minor influence. But this is an opinion not a proven fact. Removing sediment upstream on Dead Creek will probably only remove very coarse sand, which is the first to settle out either in the creek or when it enters the lake.

The geotube could retain or create wetland and is valid for that reason, but not to trap sediment.

Build a sediment trap downstream of the mouth of Dead Creek? (Discussion of details)

There are two types of sediment sampling. In evaluating the make-up of sediment that is being deposited, bottom sediment samples are usually taken first. In 2003, some bottom sediment samples were taken. The percent finer by weight of large particles (gravel and sand) is determined by putting the sample through various sieve sizes. This is an easy test to conduct; it can be and was preformed on Lake Sinnissippi samples at the Rock Island District. Sample LS5 shown below is in the vicinity of Dead Creek but farther out toward the lake. It is also useful to know the distribution of silt and clay in a sample. This test is more complicated and when I needed this information for a project several years ago it was obtained under contract for about $150 per sample. As can be seen from the plot, about 40 percent by weight of LS5 is made up of silt and clay.



Another type of sediment sample is the suspended sediment sample. Usually most sediment is transported during floods. The idea is to capture some of the flowing water from all depths of the stream and then determine the particle make-up contained in the sample. This is useful in estimating the total sediment transport of a stream as it captures particles that are often too fine to settle and become part of the sediment sample.

To determine the usefulness of a sediment trap, I guessed the travel time from the mouth of the creek to the proposed geotube site (2,500 seconds). Then I estimated the settling time for the various particles usually contained or examined in sediment transport studies. I would expect all particles with a settling time less than the travel time to fall out and become bottom sediment.

Travel Time: The distance from the mouth of Dead Creek to the proposed barrier is about 1,500 feet. At the location of the proposed barrier the width is at least five times the width of the stream. Assume a stream velocity of 3 ft per second (which seems high). This means that it takes water in the stream 500 seconds to travel 1,500 feet, while it takes water in the lake above the proposed barrier about 2,500 seconds to travel from the creek mouth to the proposed barrier. Now look at the table below and see how many particles will have time to settle out within 2,500 seconds. Everything except clay, very fine silt, and fine silt will have settled out by the time water carrying it enters the main part of the lake. This is because when the water from Dead Creek enters the lake it spreads out and slows down. There is already a natural trap in existence created by the land on either side of the creek.

Settling Time was determined by stokes law.
An Internet source of settling equation and calculator
http://www.ajdesigner.com/phpstokeslaw/stokes_law_terminal_velocity.php

Stokes Settling Velocity Equation (cm/sec) =

{G x (Density particle-Density fluid) x Particle Dia^2} / 18 x Viscosity fluid

Variable Name = value
G = gravitational acceleration = 980 cm/sec2
Density particle = specific gravity (quartz) = 2.65 g/cm3
Density of fluid = specific gravity tap water 20 dec C .9982 g/cm3
Viscosity fluid = tap water 20 dec C 0.01002 g/cm sec 1/02 g/m sec
Diameter of particle = Dia^2 cm

The above equation was evaluated for a particle diameter of 1 cm giving an answer of 8975.1 cm/sec. To evaluate different particle sizes square the particle diameter (in cm) and multiply by 8975.1 for the settling velocity answer in cm/sec. This has been done and appears in the table below. Settling times were computed in seconds and also converted to minutes, hours, and days. A map of the lake shows the water in the vicinity of the proposed project to be two (60.9 cm) to three feet (91.4 cm), so a distance of 70 centimeters was used to calculate settling time.

1foot= 30.48 cm

Table of Settling times for Various Particles to settle 70 Centimeters

Class	Mean Dia	Settling Vel	Settling time			
	Cm	cm/s	Seconds	Minutes	Hours	Days
Clay	.0003	0.0008	86,660	1,444	24	1.00
Very Fine Silt	.0006	0.0022	31,197	520	9	0.36
Fine Silt	.0011	0.0109	6,446	107	2	0.07
Medium Silt	.0023	0.0475	1,474	25	0.41	0.02
Coarse Silt	.0045	0.1817	385	6	0.11	n/a
Very Fine Sand	.0088	0.6950	101	2	0.03	n/a
Fine Sand	.0177	2.8118	25	0.41	0.01	n/a
Medium Sand	.0345	10.6826	7	0.11	n/a	n/a
Coarse Sand	.0707	44.8619	2	0.03	n/a	n/a
Very Coarse Sand	.141	178.4340	0.39	0.01	n/a	n/a

It might be possible to obtain the make-up of runoff sediment by talking to the NRCS. The NRCS (old soil conservation service) often published maps of soil types. In one of the Lake Sinnissippi District reports, the soil is described as sand silt loam. I have seen website data in Iowa that estimates the percent composition and particle size for studies the NRCS does to compute erosion from crop land. Could the district see if this is available in Wisconsin?

Building the barrier may have other reasons to recommend it, but it will not substantially reduce sediment transport into the lake. Most sediment will settle out naturally anyway without the Geotube.

Appendix C

Plates

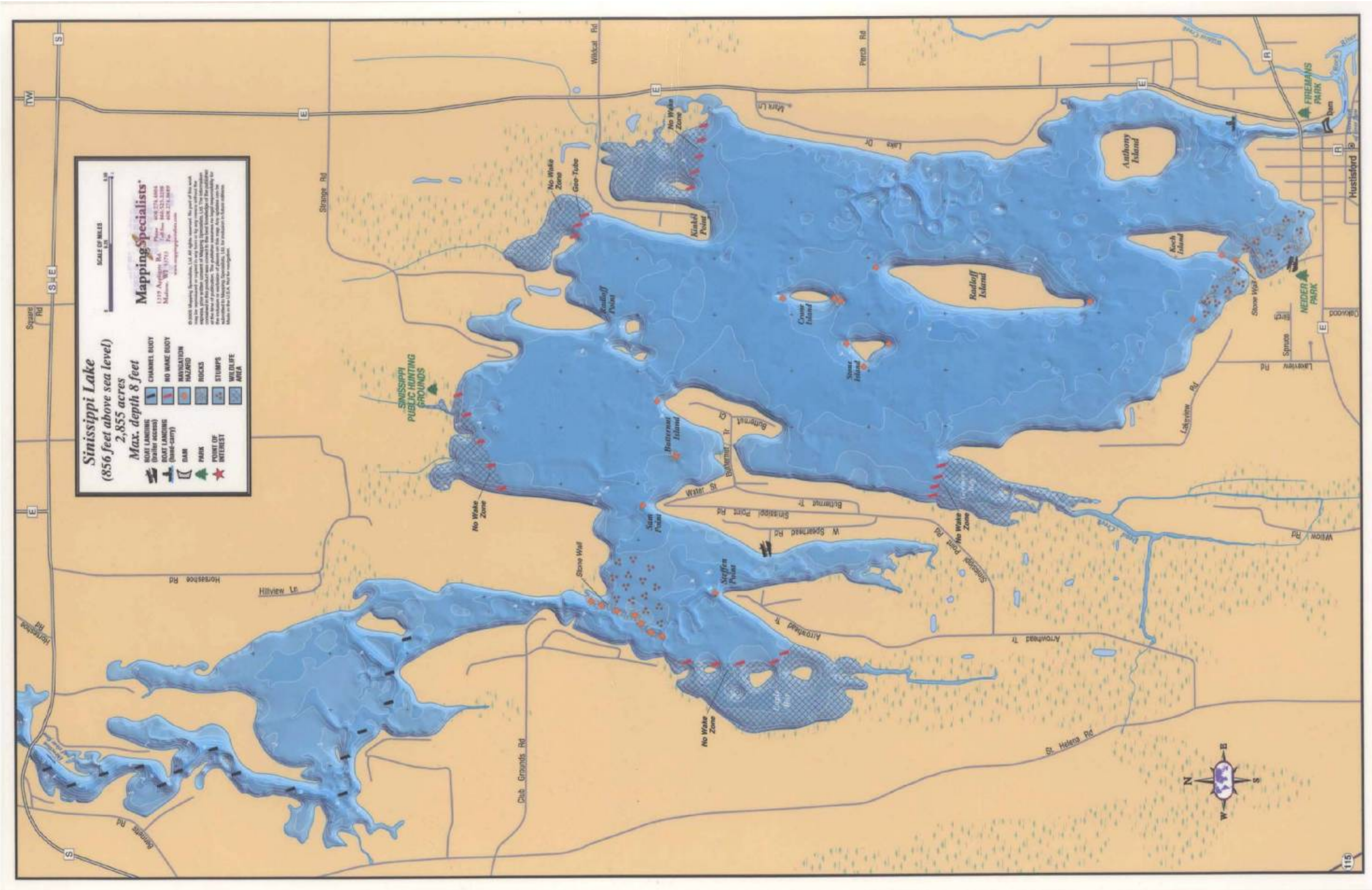


Plate 1 2003 Water Depths Courtesy of Mapping Specialists

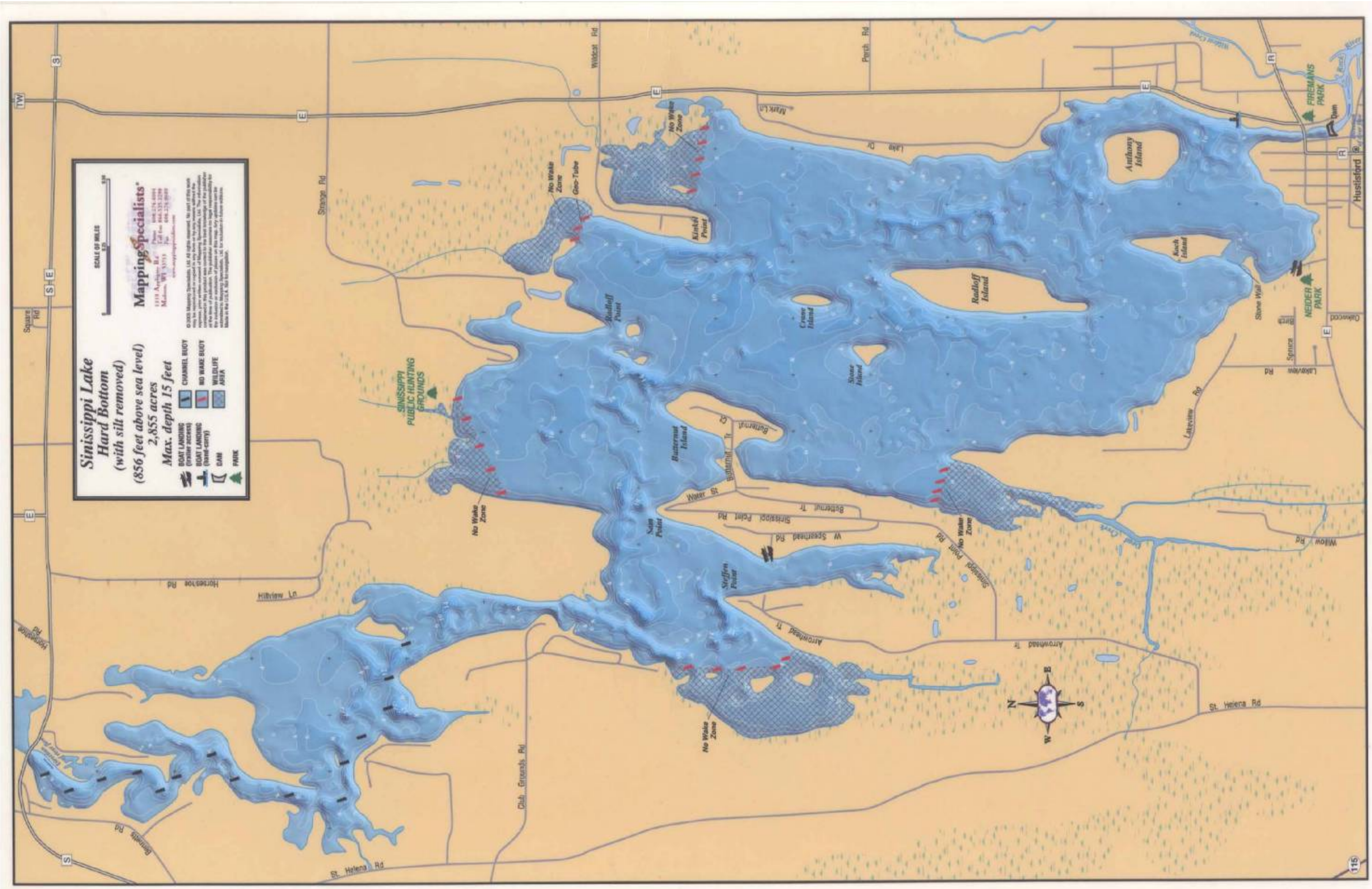


Plate 2 2003 Lake Silt Depths Courtesy of Mapping Specialists

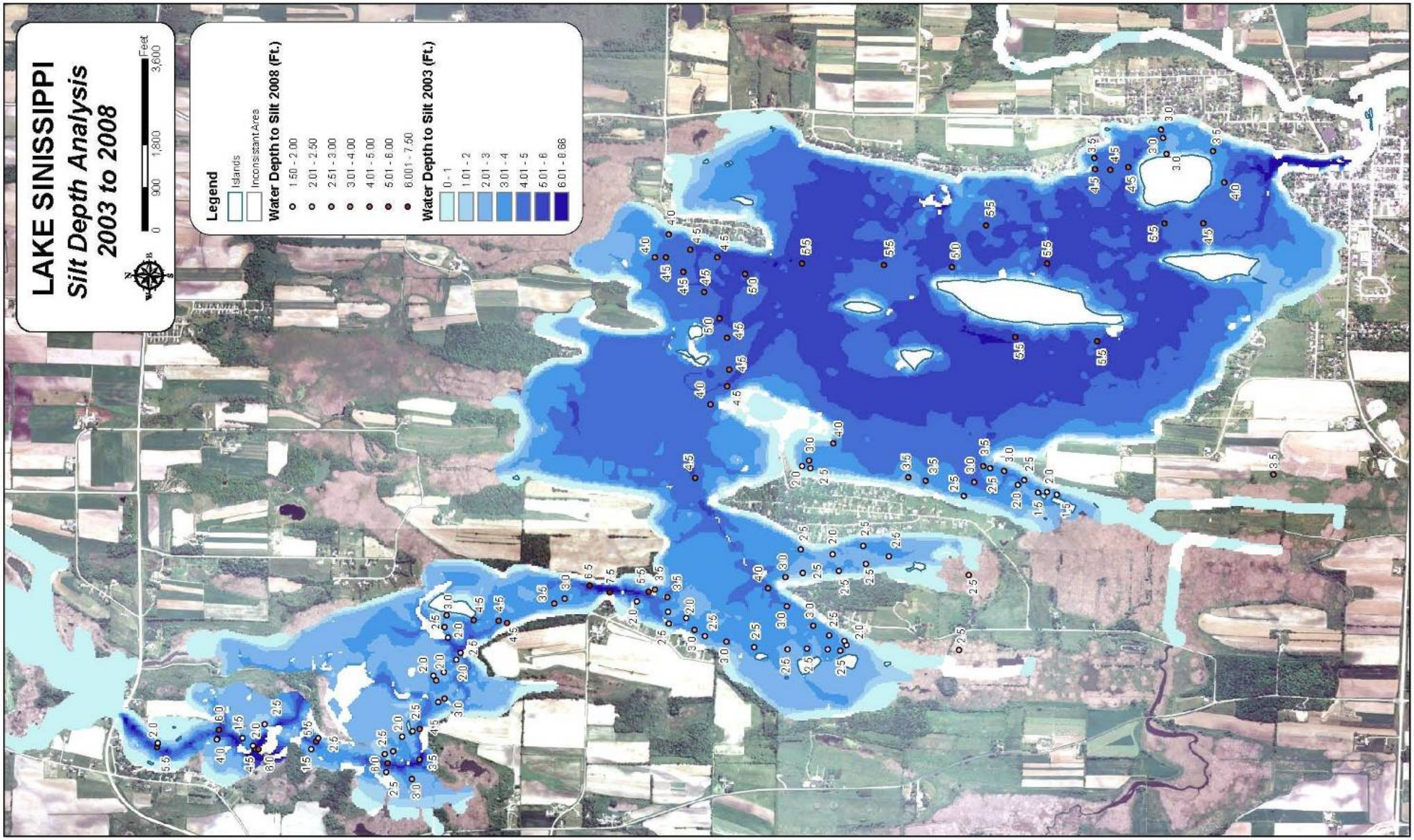


Plate 3 2003 to 2008 Lake Silt Depth Analysis

Lake Sinissippi Dredging Depths

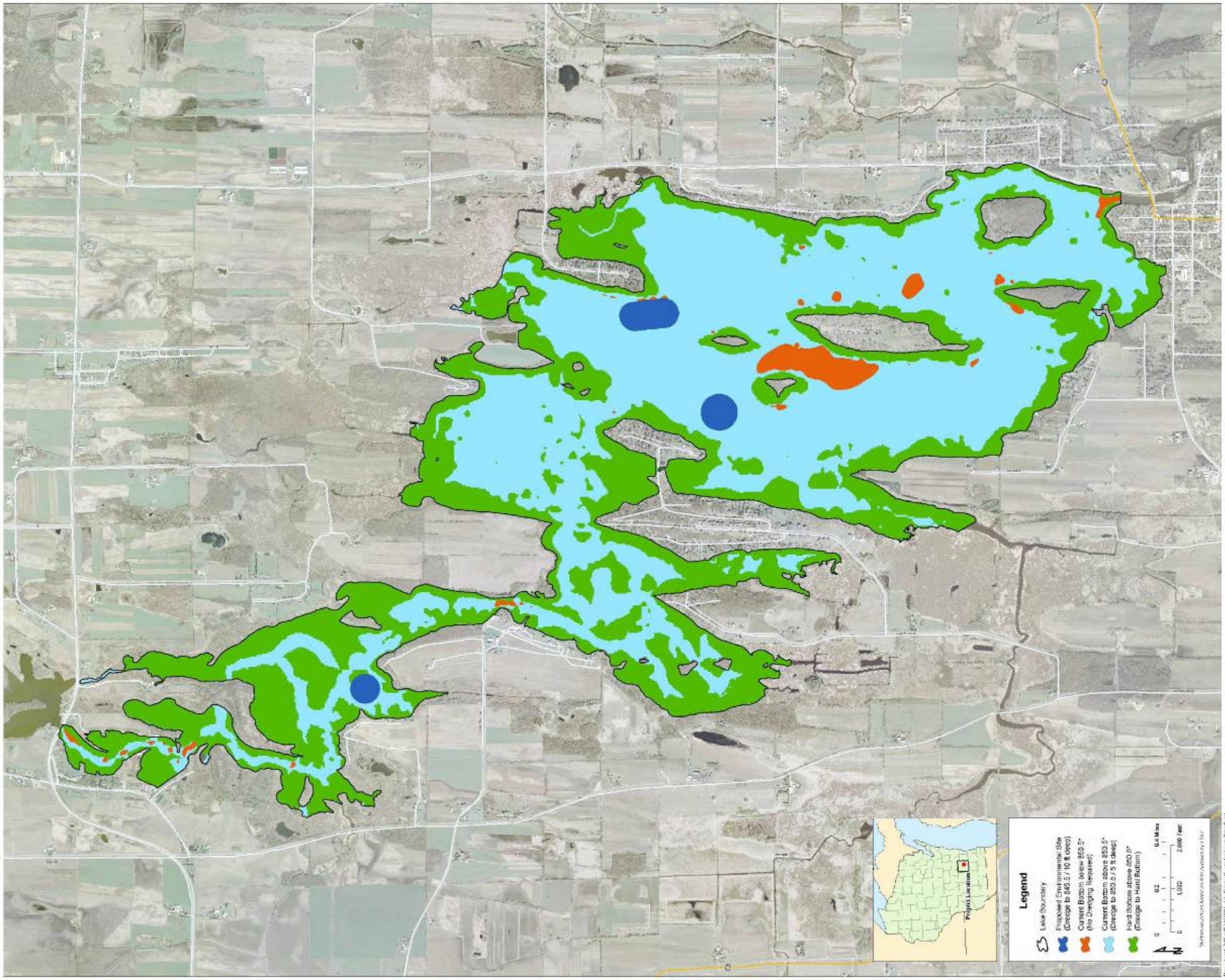


Plate 4 Dredging Depths

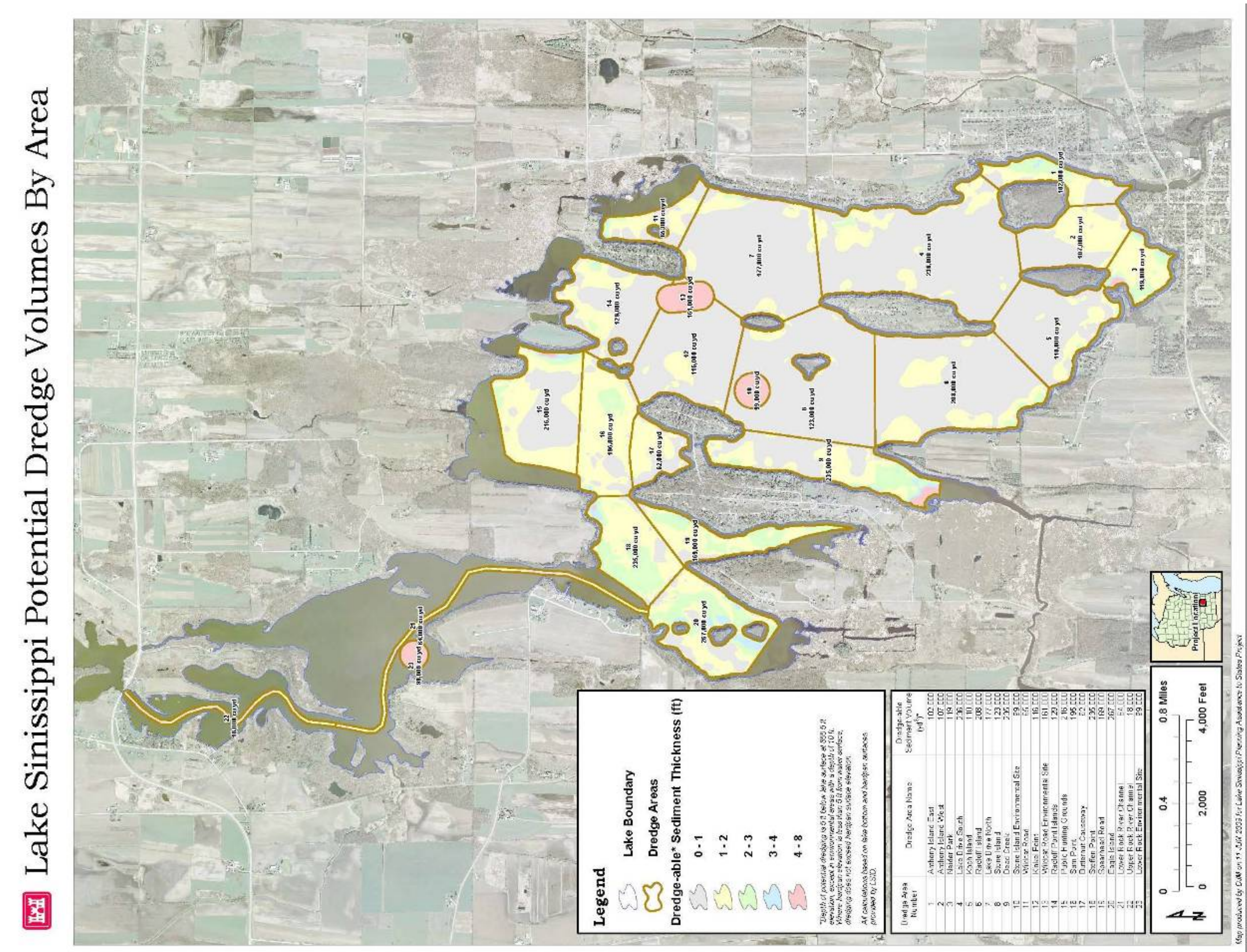
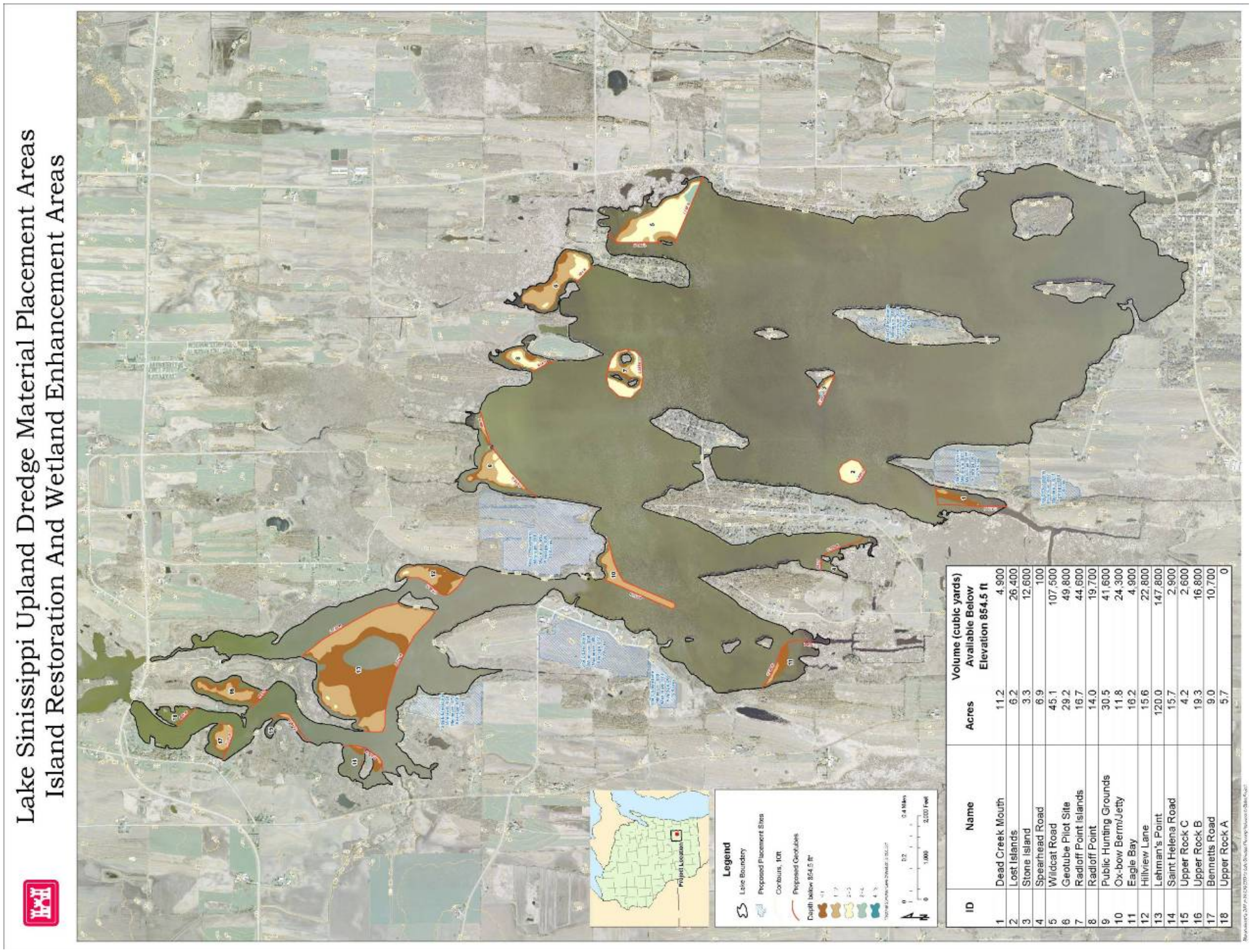


Plate 5 Potential Dredging Areas and Volumes



ID	Name	Acres	Volume (cubic yards) Available Below Elevation 854.5 ft
1	Dead Creek Mouth	11.2	4,900
2	Lost Islands	6.2	26,400
3	Stone Island	3.3	12,600
4	Spearhead Road	6.9	100
5	Wildcat Road	45.1	107,500
6	Geotube Pilot Site	29.2	49,800
7	Radloff Point Islands	16.7	44,600
8	Radloff Point	14.0	19,700
9	Public Hunting Grounds	30.5	41,600
10	Ox-bow Berm/Jetty	11.8	24,300
11	Eagle Bay	18.2	4,900
12	Hillview Lane	15.6	22,800
13	Lehman's Point	120.0	147,800
14	Saint Helena Road	15.7	2,900
15	Upper Rock C	4.2	2,600
16	Upper Rock B	19.3	16,800
17	Bennetts Road	9.0	10,700
18	Upper Rock A	5.7	0

Plate 6 Dredged Material Placement Areas

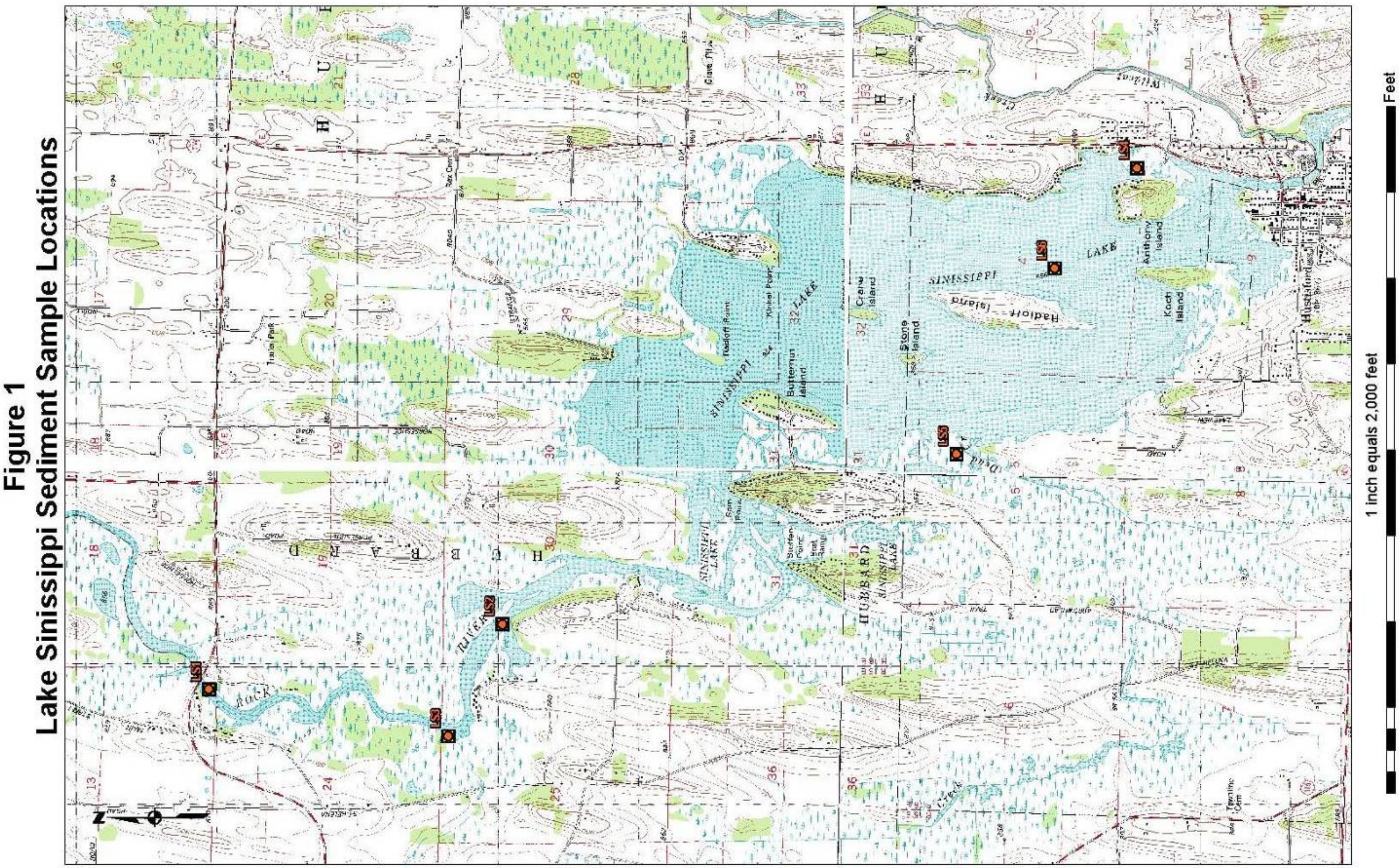


Plate 7 2003 Sediment Sample Locations

Plate 8 Historical Wetlands

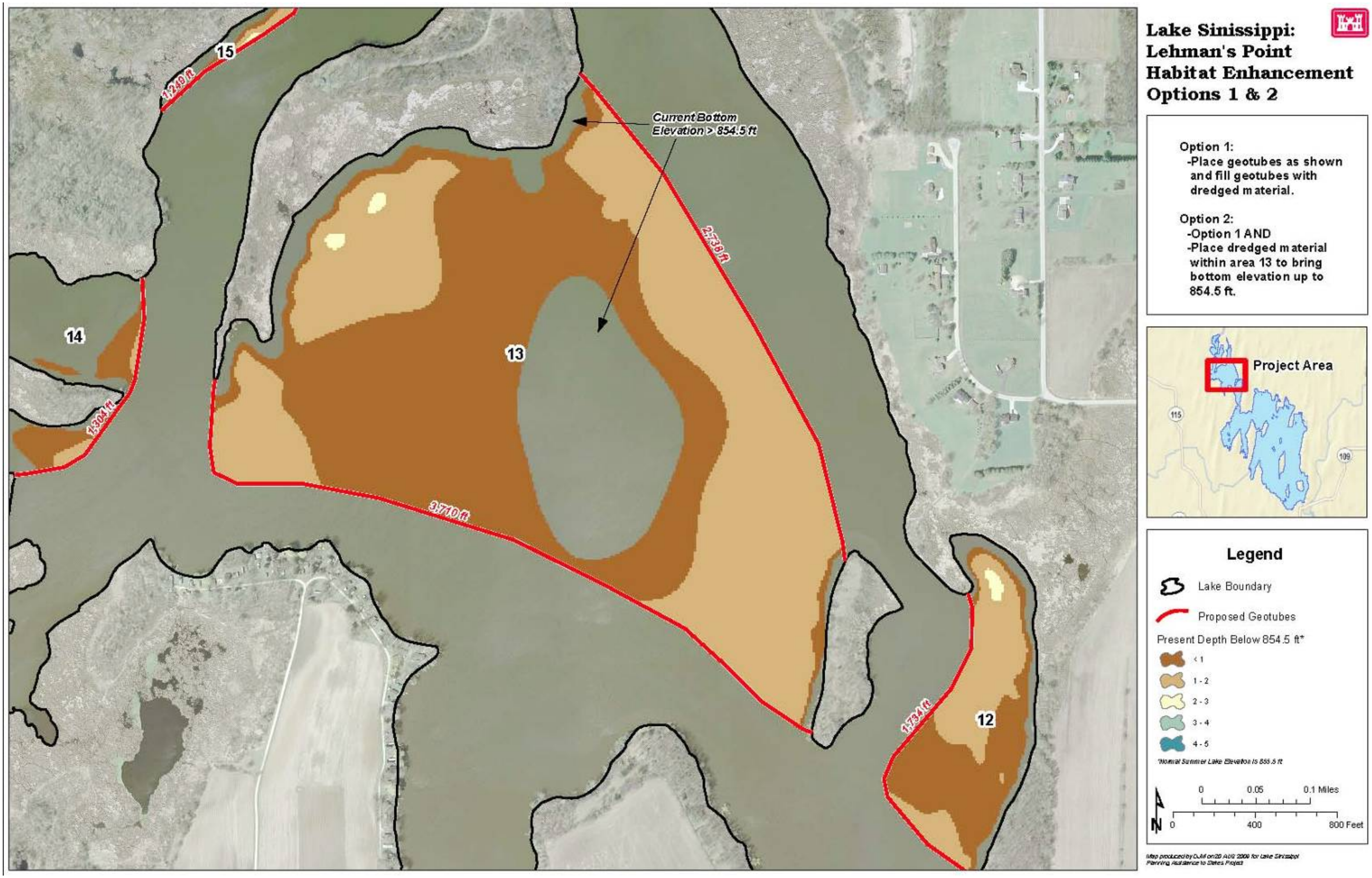


Plate 9 Lehman's Point Habitat Enhancement Options 1 & 2

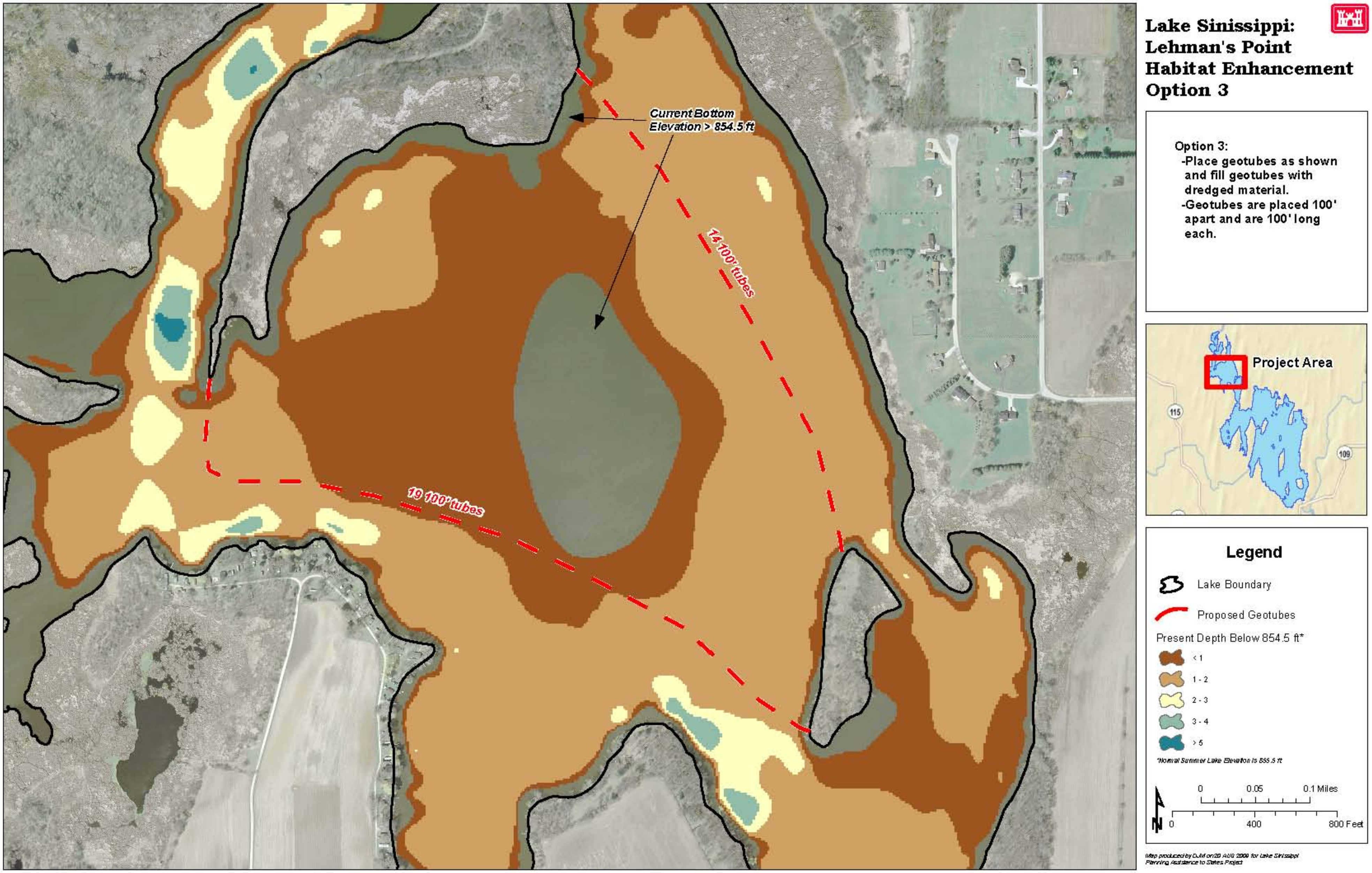
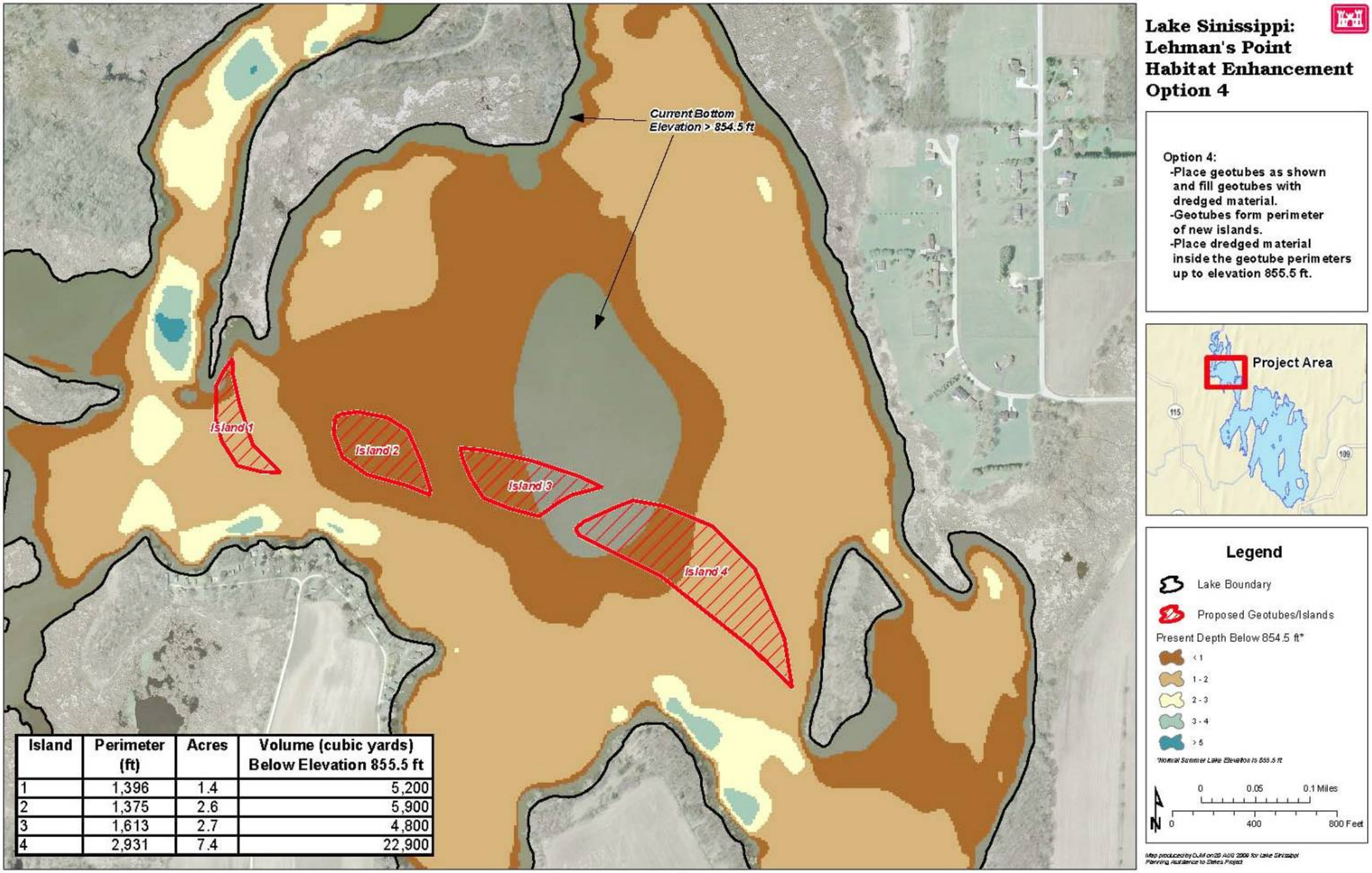


Plate 10 Lehman's Point Habitat Enhancement Option 3



Island	Perimeter (ft)	Acres	Volume (cubic yards) Below Elevation 855.5 ft
1	1,396	1.4	5,200
2	1,375	2.6	5,900
3	1,613	2.7	4,800
4	2,931	7.4	22,900

Plate 11 Lehman's Point Habitat Enhancement Option 4

Lake Sinissippi Erosion Category By Parcel

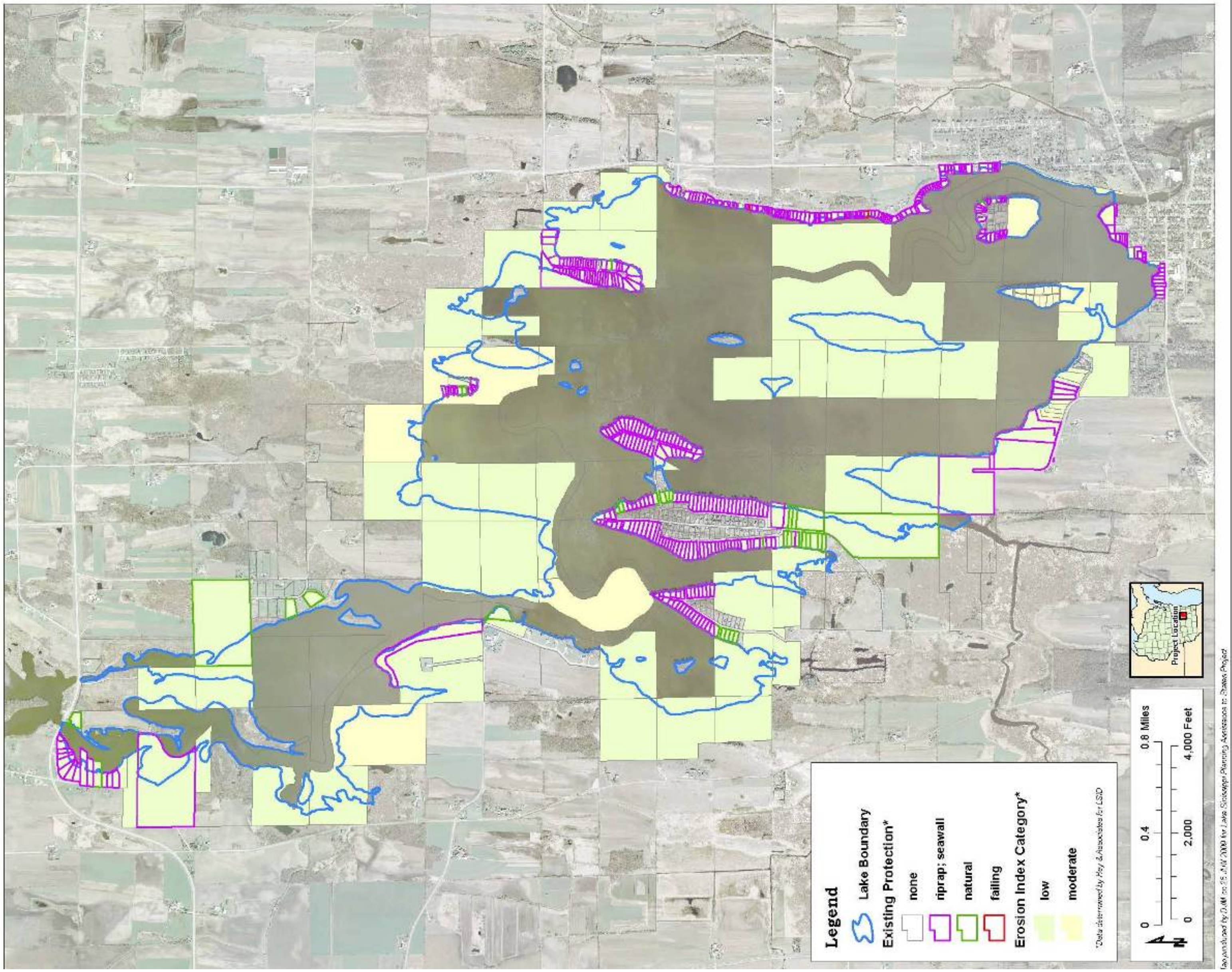


Plate 12 Erosion Category by Parcel

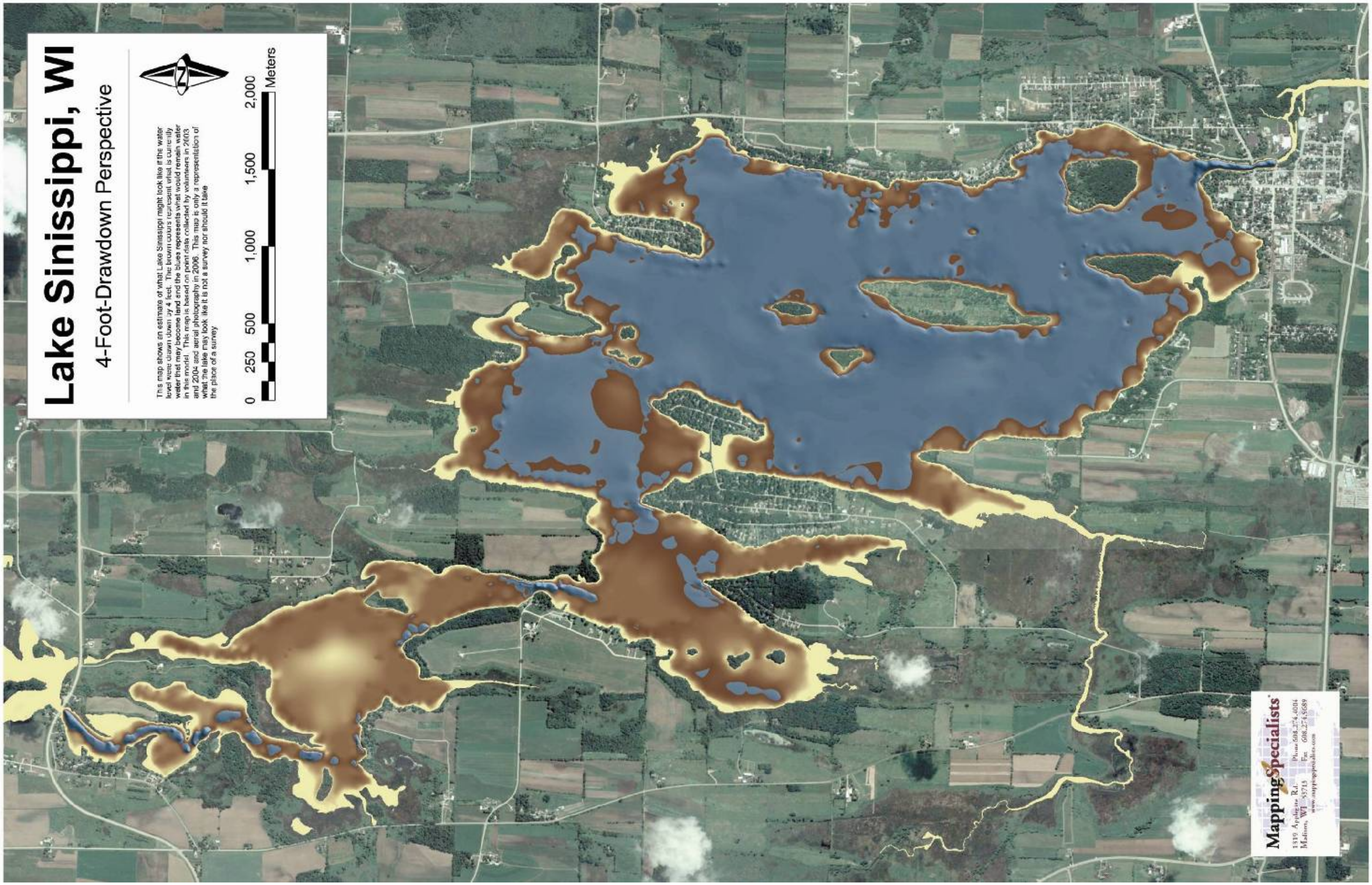


Plate 13 Drawdown Perspective Courtesy of Mapping Specialists